Electronic Engineering

the *Versatile*

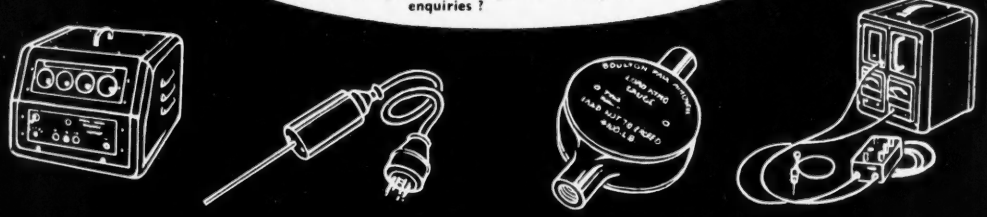
6 Channel C.R.T. Film Recorder

One of the highlights of our range. This instrument is designed for the recording on to 35 mm. film of up to six physical variables simultaneously. It is ideally suitable for vibration analysis in the laboratory or in industry.

Our considerable experience in the field of electronic instrumentation may be put to good use in solving your problem.

May we send you our catalogue or invite your enquiries ?

BOULTON PAUL AIRCRAFT LTD
WOLVERHAMPTON



DATA for the Designers File

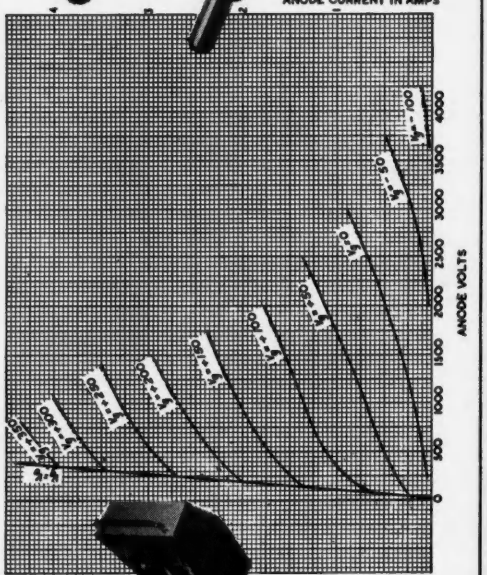
The Ediswan ES.833 is a high mu triode particularly suitable for use as an R.F. Power Amplifier, Oscillator or Class B modulator, and is an excellent valve for industrial R.F. heater equipment.

The anode and grid connections are brought out at the top and are taken through metal to glass seals to heavy current terminals. As a result of this construction the valve is exceptionally efficient at higher radio frequencies and may be operated under class 'C' CW conditions at a maximum input of 2kW at frequencies up to 30 Mcs. At reduced input rating it is possible to operate the valve as high as 75Mcs.

RATING

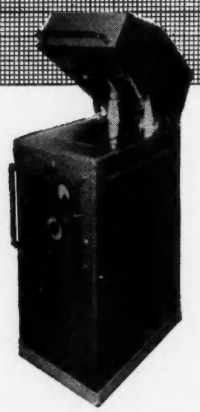
Filament Voltage (volts)	V_f	10.0
Filament Current (amps)	I_f	10.0
Maximum Anode Voltage (volts)	$V_{a\,(max)}$	*4,000
Maximum Anode Dissipation (watts)	$W_{a\,(max)}$	*400
Amplification Factor	μ	35
Maximum Operating Frequency at full rating		*30 Mc/s

* *Additional cooling will be required when operated at Full ratings at maximum Frequency.*
At higher frequencies anode voltage and input must be reduced.



REDIFON 1¼ KW H.F. Plastic pre-heater uses an ES.833 Oscillator.

This new industrial heater will plasticise up to 16 oz. of general purpose moulding powder preforms per minute. Output of this equipment is 1.3kW at 18 Mc/s.



EDISWAN

INDUSTRIAL AND TRANSMITTING VALVES

THE EDISON SWAN ELECTRIC CO. LTD.
155 CHARING CROSS ROAD, LONDON, W.C.2

Member of the A.E.I. Group of Companies

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VES
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54

CLASSIFIED ANNOUNCEMENTS

The charge for these advertisements at the LINE RATE (if under 1" or 12 lines) is: Three lines or under 7/6, each additional line 2/6. (The line averages seven words.) Box number 2/- extra, except in the case of advertisements in "Situations Wanted," when it is added free of charge. At the INCH RATE (if over 1" or 12 lines) the charge is 30/- per inch, single column. Prospectuses and Company's Financial Reports £14. 0s. 0d. per column. A remittance must accompany the advertisement. Replies to box numbers should be addressed to: "Electronic Engineering," 28, Essex Street, Strand, London, W.C.2. Advertisements must be received before the 14th of the month for insertion in the following issue.

OFFICIAL APPOINTMENTS

ADMIRALTY, BRITANNIA R.N. COLLEGE, DARTMOUTH. The Civil Service Commissioners invite applications from men for 3 pensionable posts as Lecturer or Senior Lecturer—1 in Mathematics, 1 in Physics and Mechanics, and 1 in History. Posts to be taken up by April 1955. Age at least 23 on 1st September, 1954. Normally appointment to the senior grade will not be made under age 30 but it will depend largely on academic qualifications and teaching experience. Candidates must have an appropriate honours Degree. Teaching experience desirable. Salary scales (at present under review)—Lecturers £440-£790, Senior Lecturers £890-£1,160. Starting salary above minimum in appropriate cases. Full particulars and application forms from Secretary, Civil Service Commission, 6 Burlington Gardens, London, W.1, quoting No. 4397/54. Completed forms must be returned by 10th December, 1954. W 2615

ASSISTANTS (SCIENTIFIC). The Civil Service Commissioners invite applications for pensionable posts. Applications may be accepted up to 31st December, 1954, but early application is advised as an earlier closing date may be announced either for the competition as a whole or in one or more subjects. The Interview Board will sit at frequent intervals. Age at least 17½ and under 26 years of age on 1st January, 1954, with extension for regular service in H.M. Forces, but candidates over 26 with specialized experience may be admitted. Candidates must produce evidence of having reached a prescribed standard of education, particularly in a science or mathematical subject. At least two years' experience in the duties of the class gained by service in a Government Department or other civilian scientific establishment or in technical branches of the Forces essential in one of the following groups of scientific subjects: (i) Engineering and physical sciences. (ii) Chemistry, bio-chemistry and metallurgy. (iii) Biological Sciences. (iv) General (including geology, meteorology, general work ranging over two or more groups (i) to (iii) and highly skilled work in laboratory crafts such as glass-blowing). Salary £250 (at 18) to £520 (men) or £435 (women). Starting pay up to £380 (men) or £340 (women) at 25. Somewhat less in provinces. Opportunities for promotion. Further particulars and application forms from Civil Service Commission, Scientific Branch, 30 Old Burlington Street, London, W.1, quoting No. S 59/54. W 2552

NORTHAMPTON POLYTECHNIC, E.C.1. Department of Electrical Engineering requires a Grade III Laboratory Technician for development and construction of electrical computing apparatus. The duties initially will be entirely confined to this work and the post will provide valuable experience and training in this important field. Day off a week to attend classes leading to H.N.C. or Degree in electrical engineering. Salary: age 16 £3 13s. 6d. p.w. to £401 p.a. at approx. age 26, plus supplement for certain qualifications. Apply with full particulars to Secretary. W 2608

MINISTRY OF SUPPLY requires Engineers at Woolwich Common for administration and control of (a) Inspection and testing of high voltage high power pulse systems (ref. D 544/54A) or (b) provisioning, maintenance and calibration of test gear in high voltage pulse, radar and HF fields and for vibration and climatic testing (ref. D.452/54A). Qualifications. British of British parents. Recognised engineering apprenticeship or equivalent in electronics and A.M.I.C.E. or M.E. or E.E. or exempting qualifications. Experience in (a) inspection methods for electronic equipments or (b) fault finding, circuit modifications, etc., highly desirable. Salary. Within £650 (age 25)—£1,000. Not established but opportunities to compete for establishment may arise. Application forms from M.O.L. N.S.T.&S.R., 26 King Street, London, S.W.1, quoting appropriate reference. Closing date 10th December, 1954. W 2581

MINISTRY OF SUPPLY requires Senior Scientific Officers at Royal Aircraft Establishment, Farnborough, Hants., to work on research in and development of radio and other fuzing techniques for guided weapons and bombs. Qualifications: 1st or 2nd class Honours Degree or equivalent in Physics or Electrical Engineering with at least 3 years post graduate research experience. Salary within range £935-£1,090. Women somewhat less. F.S.S.U. Benefits may be available. Application forms from M.L.N.S., Technical and Scientific Register (K), 26, King Street, London, S.W.1, quoting A320/54A. Closing date 11th December, 1954. W 2606

PHYSICIST OR ELECTRICAL ENGINEER required at Ministry of Supply London H.Q., responsible for development of air photographic equipment. Duties include preparation of contract proposals for research and development projects, scrutiny of specifications, supervision of the work and assessment of results. Quals.—1st or 2nd class honours Degree or equivalent qualifications in Physics or Electrical Engineering. Research experience in physical optics, photo-electricity, photographic processes or electronics required. An aptitude for originating and supervising research and development projects desirable. Salary within range Senior Scientific Officer (min. age 26) £975-£1,150. Scientific Officer (min. age 21) £470-£855. Women somewhat less. F.S.S.U. benefits may be available. Application forms from M.L.N.S., Technical & Scientific Register (K), 26 King Street, London, S.W.1, quoting A291/54A. W 2565

PRINCIPAL SCIENTIFIC OFFICER required by Ministry of Supply, Royal Aircraft Establishment, Farnborough, Hants, to take charge of a project group responsible for development in Industry of a guided weapon. Qualifications: 1st or 2nd Class Honours Degree or equivalent in Physics or Engineering with considerable research and development experience in Instrument-Electronics field or related system of engineering in Aircraft Industry. Minimum age 31. Salary in range £1,090-£1,472. Women somewhat less. F.S.S.U. benefits may be available. Application forms from M.L.N.S., Technical and Scientific Register (K), 26 King Street, London, S.W.1, quoting A306/54A. W 2576

PROFESSIONAL ENGINEERS in various Government Departments. The Civil Service Commissioners invite applications for pensionable posts in a wide variety of mechanical and electrical engineering duties. Candidates must be under 35 on 1st January, 1954, with extension for regular service in H.M. Forces and up to two years for permanent civil service. For the Post Office they must be at least 21, for the Ministry of Supply and Ministry of Transport and Civil Aviation at least 23, and for all other Departments at least 25 on that date. Generally a candidate must possess a University Degree in Engineering or be a Corporate Member of one of the professional institutions—Mechanical Engineers, Electrical Engineers, or Civil Engineers or have passes in, or exemption from, Sections A or I and B or II of the corresponding Associate Membership examinations. Exceptionally candidates of high professional attainment, but without the specified qualifications, may be admitted. For some posts Associate Fellowship of the Royal Aeronautical Society or an Honours Degree in Physics or Engineering will be accepted. London salary scale (Men) £650 (at age 25) to £1,000. Starting salary according to age up to £900 at 34. Candidates entering below age 25 will start at salaries varying from £450 at age 21 to £570 at age 24. Prospects of promotion. Salaries of next higher grades are £1,000-£1,320 and £1,375-£1,575. Somewhat lower for women and in the provinces. Further particulars and application forms from Civil Service Commission, Scientific Branch, 30, Old Burlington Street, London, W.1, quoting No. S85/54. Completed applications should be returned as soon as possible and in any case before 31st December, 1954. W 2594

THE COLLEGE OF AERONAUTICS. Chair of Aircraft Electrical and Electronic Engineering. The Governing Body invites applications for the newly created post of Professor and Head of the Department of Aircraft Electrical and Electronic Engineering. Candidates will be expected to have a sound general knowledge of the whole field of aircraft electrical and electronic engineering, as well as extensive and up-to-date knowledge and experience of some important branch. Candidates must be capable of administering a Department, teaching and supervising studies at a post-graduate level, and engaging in research as well as directing a programme of research within the Department and in co-operation with other Departments in the College. The salary range for the post is £1,700 to £2,000 per annum, with superannuation under F.S.S.U. and family allowances. The initial salary will be dependent upon the qualifications and experience of the successful candidate. Applications, giving full details of qualifications and experience, and quoting the names of three referees, should be addressed to The Principal, The College of Aeronautics, Cranfield, Bletchley, Bucks, preferably not later than 30th November, 1954, or within two weeks of the date of this advertisement. Further particulars available. W 2564

VACANCIES IN GOVERNMENT SERVICE Skilled Craftsmen. Vacancies exist for Skilled Craftsmen with experience in the use of electronic equipment, radio equipment and modern communications practice. Opportunities for permanent and pensionable posts. Apply in writing: Personnel Officer, G.C.H.Q., 53, Clarence Street, Cheltenham. W 1210

SITUATIONS VACANT

***The engagement of persons answering these advertisements must be made through a Local Office of the Ministry of Labour or a Scheduled Employment Agency if the applicant is a man aged* 18-64 *inclusive or a woman aged* 18-59 *inclusive unless he or she, or the employment, is excepted from the provisions of the Notification of Vacancies Order,* 1952.**

A. C. COSSOR LTD., Highbury, London, N.5, have vacancies for all engineering grades and Designer/Draughtsmen in their Research and Development Division 5. The programme of work includes Radio Communications, Television, Electronic Instruments, Primary and Secondary Ground and Airborne Radar, and Navigational Aids. In particular vacancies exist for Senior Engineers of good academic qualifications, and industrial experience; for recently qualified scientists and engineers with or without experience who wish to train for a career in the electronic industry; and for sen. Draughtsmen experienced in any of the above types of work. Salaries offered are consistent with present trends in the industry and the London cost of living; pension, welfare, and medical services are provided. Application in writing to the Personnel Manager, Mr. L. V. Cartwright. W 2561

AN ATTRACTIVE future offered to a Senior Electronic Engineer in young and rapidly expanding organisation producing Electronic Instruments. Essentials are good technical education and wide experience together with the ability to "get things done." All replies answered and treated as confidential. Rivlin Instruments Ltd., 7a Maitland Park Villas, London, N.W.3. W 1214

AN OLD ESTABLISHED ENGINEERING COMPANY in the Birmingham area have a vacancy for a young man (aged 25/27) for training as a Service Engineer on their outside staff. National Service must have been completed. Apprenticeship and actual industrial experience in Electrical or Electronic work with emphasis on fault finding and testing of production equipment necessary. Very good prospects to successful candidate. Apply giving full details of experience, age and wages required quoting "Service" to Box No. W 2593.

SITUATIONS VACANT (Cont'd.)

The engagement of persons answering these advertisements must be made through a Local Office of the Ministry of Labour or a Scheduled Employment Agency if the applicant is a man aged 18-64 inclusive or a woman aged 18-59 inclusive unless he or she, or the employment, is excepted from the provisions of the Notification of Vacancies Order, 1952.

AN OPPORTUNITY occurs in progressive manufacturing concern in London area for Engineer aged 25/35 with electrical or physicist degree, on development and research work on high frequency telecommunication cable and associated testing equipment. Salary will be commensurate with qualifications and experience. Apply giving full particulars to Box No. W 1165.

ASSISTANT (m. or f.) for Patent and Information Dept. in connection with electronic engineering. Suitable for electronic engineer with flair for documentation and patent work. Training if required. Languages an advantage. Permanent progressive post. Pension scheme. Write stating salary required to Staff Manager, Thorn Electrical Industries Ltd., 105 Judd Street, W.C.1. W 2556

ARE YOU A YOUNG SCIENCE (ELECTRONICS) GRADUATE of good personality and background (Age 22-24, preferably no previous business experience) who has the inclination to make use of his knowledge so as to become a Business Executive? You will, if selected, embark on an interesting and well paid career. This opening is in London. Please apply, giving fullest particulars in confidence to Box No. W 1194.

ASSISTANT ELECTRONIC ENGINEER required for design and construction of specialized industrial electronic apparatus. Applicants should possess a Higher National Certificate or similar qualification in radio engineering with 4/5 years' practical experience. Knowledge of D.C. amplifiers would be an advantage. National Service must be over. Salary according to qualifications and experience. Good opportunities for advancement. Pension scheme. Apply in writing to the Personnel Manager, R.13, C.A.V. Limited, Warple Way, Acton, W.3. W 2559

ASSISTANT ENGINEERS. 25-30 required for electronic and mechanical work near London. Good prospects of promotion, interesting work, and a pension scheme await suitably qualified graduates. Apply with full details of past experience to Box No. W 2599.

AUTOPHONE LIMITED require qualified Development Engineer (Degree or equivalent) for interesting and varied work on telephone and Electronic equipment. Design and practical experience essential. Write fullest particulars to 539 Wandsworth Road, S.W.8. W 1149

BELGIUM. Opportunity by Brussels manufacturer for fully qualified technician and M.Sc., experienced in V.H.F. and U.H.F. radio communications and electronics. Application in writing stating full references and experience to Telecom S.A. 5, Rue Vergote, Brussels, Belgium. W 1189

BERRY'S (SHORT WAVE) LTD., have vacancies for Senior and Junior Sales Staff. Please write fully giving details of experience, age, salary required, etc., to 25 High Holborn, W.C.1. W 1171

BRITISH ACOUSTIC FILMS LTD., Woodger Road, W.12, have vacancies for Senior and Junior Development Engineers to work on sound recording and reproducing equipment and associated apparatus of all types. Salary according to experience and qualifications. Pension Scheme. Application should be made, in writing, to the Personnel Manager. W 1208

CANADA. Hunt Capacitors (Canada) Limited, Ajax, Ontario, offer openings to Engineers who contemplate emigrating to Canada, and who have the required qualifications as set out below. 1. Laboratory Assistant. Ordinary or Higher National Certificate in Electrical Engineering. Age 25/30. Preference given to applicants with experience of process control in the manufacture of fixed paper capacitors and/or electrolytics. Engineers with experience of valve manufacture or quartz crystal manufacture will also be conside red. 2. Chief Inspector. Ordinary or Higher National Certificate in Electrical or Radio Engineering. Age 23/25. Applicants should have good knowledge of test gear design and be capable of carrying out occasional maintenance. Reply giving full details of education, experience, and positions held in present and previous employment to Personnel Manager, A. H. Hunt (Capacitors) Limited, Bendon Valley, Garratt Lane, S.W.18. W 1215

CHIEF DRAUGHTSMAN required by well established company in North London area. Must have experience in design of distribution transformers up to 500 kVA. Excellent conditions: Group assurance scheme. Write Box No. W 1191.

CHIEF ELECTRONIC ENGINEER required to take charge of a Division specializing in the development of industrial and laboratory instruments. The work involves the use of modern pulse and servo techniques, etc., in a variety of new applications, and presents considerable scope for ingenuity. Candidates must have had previous experience in controlling a development team and possess good academic qualifications. The position is a responsible one and carries a very substantial salary. Applications giving full particulars of experience and qualifications to Personnel Manager, Elliott Bros. (London) Ltd., Century Works, Lewisham, S.E.13. W 2611

COMMUNICATION ENGINEERS and Draughtsmen. The expanding programme of the Transmission Department offers vacancies in both senior and junior categories for Line Transmission Laboratory Engineers, and Apparatus Design Engineers, and also for Draughtsmen with experience in telecommunications or light current engineering. Specialist experience in any branch of Line Transmission Engineering is desirable for some of the posts. Positions offered are on the Company staff with contributory Pension Fund and usual staff conditions. Applicants should write to Personnel Manager, Automatic Telephone and Electric Co. Ltd., Strowger Works, Edge Lane, Liverpool, 7, giving full details of age, qualifications, and experience. W 2602

DECCA RADAR LIMITED require an ex-Service Radar Mechanic with substantial operational experience of radar, for work on field trials at experimental Radar Installations. Applicants must be prepared to work anywhere in the United Kingdom. Age 25-35; British Nationality essential. Pension Scheme. Write quoting reference RLA/62 to Decca Radar Limited, 2 Tolworth Rise, Tolworth, Surbiton, Surrey. W 2586

DECCA RADAR LIMITED have a vacancy for a Circuit Engineer to work on advanced techniques involving subminiature construction. Previous circuit experience and British Nationality essential. Pension Scheme. Write quoting reference RLA/65 to Decca Radar Limited, 2, Tolworth Rise, Tolworth, Surbiton, Surrey. W 2585

DESIGN DRAUGHTSMAN. Leading Manufacturers require experienced man to take charge of small group responsible for complete engineering of Broadcast and Television Receivers. The post offers considerable scope with good prospects of advancement. Apply stating age, experience and salary required to The Personnel Manager, Box No. W 2562.

DESIGN DRAUGHTSMEN required by leading manufacturers of Radio, Television, domestic appliances and electronic equipment who are the largest producers of portable radio in Great Britain. Vacancies (both Senior and Junior) result from considerable expansion and development in the above fields, and offer first-class opportunities for advancement on ability. Applicants having practical experience in light electrical engineering are invited to apply, and those accepted are assured of good commencing salaries. Staff Pension Scheme. Address full particulars, in confidence, to Personnel Manager, Vidor-Burndept Limited, Erith, N. Kent. W 2570

DE HAVILLAND PROPELLERS LIMITED. Applications are invited for the following permanent and progressive positions: Research and Design Laboratory—a number of vacancies exist for senior Electronic Engineers having experience on research or design relating to special circuits operating at medium to low frequencies. Knowledge of physics an advantage. Qualifications should preferably include a good degree though H.N.C. or City and Guilds with several years' work on similar problems would prove acceptable. The work is interesting and rewarding with excellent opportunities for advancement. (Ref. 77). System Engineer-Electronic Engineer with good practical and theoretical background required to perform pre-flight measurements on a missile guidance system. Experience, initiative and adaptability required for this work. Working away from base for periods of a few days may be necessary. Any previous experience of a similar nature would be an advantage. (Ref. 78). Laboratory Assistants and Junior Electronic Engineers required for a number of posts in the Research and Design Laboratories of an advanced Guided Missile project. The work is interesting and prospects for advancement are good. For most of these posts graduates are required, or applicants holding National Certificate or City and Guilds with some practical experience. Lack of these qualifications should not prevent application being made as each case will be considered on its merit. (Ref. 80). Senior and Junior Assistant Physicists required in a Guided Missile project for research and development work. Qualifications must include a degree in physics and two years' industrial experience for the senior posts and Inter B.Sc. or equivalent for the junior posts. Knowledge of electronics an advantage. (Ref. 81). Senior and Junior Engineers for mechanical design, development and construction of up-to-date subminiature equipment. The work is of a practical nature, but knowledge of Drawing Office procedure an asset. There is also an opportunity for the development of the latest techniques in connection with this work. (Ref. 82). Please write in detail, quoting reference number of position sought, to: The Personnel Manager (Technical Employment), De Havilland Propellers Limited, Hatfield, Herts. W 2522

DESIGNER-DRAUGHTSMAN, age 25/35, with experience modern instrumentation. Post offers advancements in expanding organization handling electronic and nucleonic equipment Salary according to qualifications. Apply Box No. W 2496.

DEVELOPMENT ENGINEER required for work on R.F. circuitry and associated test equipment. National Service must be complete. Write in first instance stating experience and salary required to Sydney S. Bird & Sons, Ltd., Fleets Lane, Poole, Dorset. W 1195

DEVELOPMENT ENGINEER required for voltage regulating equipment and control gear. Well established company North London area. Write Box No. W 1192.

DRAUGHTSMAN required for light engineering work, with experience on electrical and mechanical mechanisms. Write Box No. W 1190.

DRAUGHTSMEN: Vacancies for senior draughtsmen with experience of Electronic and/or Electro-mechanical engineering required, preferably with experience of Ministry requirements. Excellent prospects with good commencing salaries; non-contributory Pension Scheme in operation. Applications will be treated in strict confidence and should give full chronological details of qualifications, experience and age to: John A. Smith Ltd., 24 Lichfield Street, Wolverhampton. W 201

CLASSIFIED ANNOUNCEMENTS
continued on page 4

HIGH FIDELITY AT REALISTIC COST

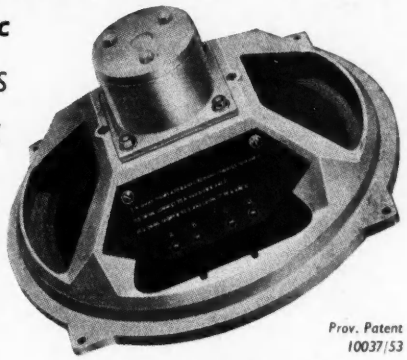
...say the experts—and the public

WORLD FAMOUS

Stentorian CAMBRIC CONE

HI-FI UNITS

The experts (including F. J. Camm, John Gilbert, P. Wilson, H. J. Barton-Chapple and L. Ormond Sparkes) have acclaimed this astounding realism of reproduction at amazingly low cost, made possible only by specialised designing and manufacturing resources. The patented Cambric Cone combines with high flux density Alcomax magnet, and robust, die-cast chassis, to produce a speaker unrivalled except at many times the price. Now available with exclusive universal impedance speech coil (at 3, 7.5 and 15 ohms) on 8", 9" and 10" models. Write for descriptive leaflets, or ask your usual dealer to demonstrate. Alternatively, these and other Stentorian speakers may be heard at our London office (109 Kingsway, W.C.2) any Saturday from 9 a.m. to noon.



Prov. Patent 10037/53

PRICES FROM 37/6.

READY-TO-ASSEMBLE

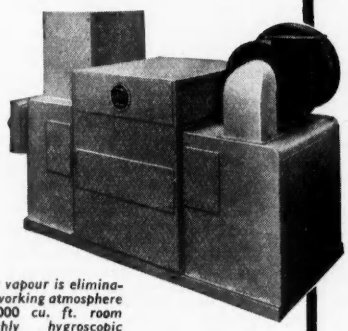
CONSOLE CABINETS

Ready - to - assemble Bass Reflex Cabinet for 10" or 12" units, in polished walnut, size 32" x 22" x 16", **£10.10.0.**

Corner Console Cabinet for 8" unit, **£5.10.0.** Full details on request.

WHITELEY ELECTRICAL RADIO CO., LTD., MANSFIELD, NOTTS

WRAPPING PACKING HANDLING does* MOISTURE *SPOIL YOUR PRODUCT



Excess water vapour is eliminated from the working atmosphere in this 40,000 cu. ft. room where highly hygroscopic materials are packed.

Serious deterioration of insulating materials is caused by moisture pick-up during manufacture, storage and maintenance of electronic equipment. High humidities also cause power break-downs in wave-guides or reduce the electric discharge of ozonisers. Such problems are prevented by the installation of BIRLEC LECTRODRYERS, with standard sizes ranging from the 100 cfh Laboratory model to units with capacities of 15,000 cfm and more.

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DRYER DIVISION OF BIRLEC LTD

TYBURN ROAD

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The engagement of persons answering these advertisements must be made through a Local Office of the Ministry of Labour or a Scheduled Employment Agency if the applicant is a man aged 18-64 inclusive or a woman aged 18-59 inclusive unless he or she, or the employment, is excepted from the provisions of the Notification of Vacancies Order, 1952.

ELECTRICAL ENGINEER required to take charge of test and development laboratory. Applicant must have some years experience in a laboratory concerned with any of the following: Capacitors, Insulation materials, Cables. Position is progressive and offers excellent scope for keen engineer. Location London E.17. Write Box No. W 1202.

ELECTRONIC ENGINEER required for research and application of electronics to vibration and stress problems. Young Engineers with good academic qualifications and some experience of this type of work are invited to apply for this post. Excellent conditions include a non-contributory Staff Pension Scheme and there are first-class prospects for the right man. Please apply with full details of qualifications, experience, etc., to the Chief Personnel Officer, Brush Electrical Engineering Co. Ltd., Loughborough, Leics. W 2580

ELECTRONIC ENGINEER required with high academic standards conversant with theory and preferably design and production of very small high-frequency electric motors. Write to Personnel Manager, Vactric Ltd., Electric Motor Division, Brunel Road, London, W.3. W 1195

ELECTRONIC ENGINEER. The unit of a well-established engineering company situated in the Portsmouth area invite applications from Senior Electronic Engineers. Applicants, who should be to Degree standard, should have a specialized knowledge of circuitry design. Salary up to £1,000 per annum. The position presents excellent opportunities to a man of good qualifications and experience. Please reply, in confidence, giving full details to Box No. W 2598.

ELECTRONIC ENGINEER required for new research laboratories to assist in the design and construction of measuring apparatus for investigating the properties of materials and assemblies under vibrational and shock loading conditions. A Degree standard in appropriate subjects and some practical research experience are required. The appointment is permanent and offers excellent prospects, with a starting salary of £800-£1,200 depending on qualifications and experience. Apply in writing to E.P.S. Ltd., Research and Development Establishment, Sittingbourne, Kent. W 1207

ELECTRONIC ENGINEERS with sound basic knowledge of low frequency techniques required for work on design and development of electronic units for servo control work. Candidates should have some practical experience and qualifications in shape of Degree. H.N.C. or City and Guilds Certificate desirable, but by no means essential (Ref. 59). Write in detail, quoting reference number of position sought to: The Personnel Manager (Technical Employment), de Havilland Propellers Limited, Hatfield, Herts. W 2433

ELECTRONIC ENGINEERS with degrees in physics or engineering required for important and interesting work on the research and development of special equipment. Good opportunity and high salary rate. Write to Managing Director, Microcell Ltd., 56, Kingsway, W.C.2. W 2555

ELECTRONIC ENGINEERS required by The General Electric Co. Ltd., Brown's Lane, Allesley, Coventry, in their Development Laboratories for work on the following items: (a) Development of Pulse Circuitry Techniques for Guided Weapons. (b) Microwave Development. (c) General Radar Circuit Development. (d) Trials Team in connection with Guided Weapons. (e) Servo-Mechanisms. (f) Test Equipment. (g) Magnetic Amplifiers. (h) Power Units including Electronic Stabilizers and Rectifiers Systems. (i) Application and Circuit theory of transistors. (j) Design of R.F. Modulators. (k) Investigation into Valve Parameters. (l) Design of Valve Test Apparatus associated with (k) above. Applicants, preferably with a Degree or an equivalent qualification, should have at least two years' experience in the development and engineering of Service equipment as well as experience in one of the above. Reply stating age, qualifications and experience to the Personnel Manager. Ref. R.G. W 2545

ELECTRONIC INSTRUMENT DRAUGHTSMEN wanted for expanding old-established business. Experience VHF and RF test equipment desirable. Age 23-40, salary according to experience and qualifications. Apply Box No. W 2497.

ELECTRONIC INSTRUMENT SALES ENGINEER required for the Midlands area in connection with the sale of a comprehensive range of industrial instruments. Candidates should be educated to Higher National standard and must have had selling experience of instruments and similar equipment. The position, which is pensionable, offers good scope for advancement. Age range 25-35. State full details of age, education, training and previous experience to Box No. W 2574.

ELECTRONICS. An exceptional opportunity is offered to a young electronic engineer possessing ability and ambition to act in a managerial capacity as head of a rapidly growing department engaged in new developments in this field. Commencing salary up to £1,250 per annum, according to qualifications and experience. Prospects depend upon initiative and personal efforts in building up successful business. Staff pensions scheme in operation. Applications, which must state full particulars of qualifications and previous experience, will be treated in strict confidence. Box No. W 2488.

ELECTRONICS DEVELOPMENT ENGINEER. Rapidly expanding company located near Aylesbury offers outstanding opportunity to a Development Engineer with a wide experience of Electronics Design. Applicants must have a sound knowledge of Communications/Pulse Techniques; be qualified by Degree or equivalent, and experience of Aerial Design would be an advantage. The post offers great scope for future advancement to a man with a good background of Industrial or Establishment experience. Full details of age, experience, qualifications and salary expected to Airtech Limited, Aylesbury and Thame Airport, Haddenham, Bucks. W 1209

ELLIOTT BROTHERS (LONDON) LIMITED. Electronic Technical Assistants. Openings exist for Technical Assistants to work on the development of new electronic equipment. The development programme affords opportunities for work in the interesting and progressive fields of laboratory and industrial measurements, instrumentation and process control, and involves the use of advanced pulse and servo techniques. Applications are invited from Graduates, holders of Higher National Certificate, and holders of City and Guilds certificates in Radio and Electronics or their equivalent. Previous experience in similarly appropriate fields will be of particular interest. Applications giving full particulars of age, qualifications etc. to Personnel Officer, Century Works, Lewisham, S.E.13. W 2610

E.M.I. ENGINEERING DEVELOPMENT LTD. have a vacancy for a Mathematician or mathematical Physicist—preferably an Honours Degree—to study and assess weapon performance. The problems require original thought and a critical approach to the data available. A knowledge of electronics would be useful but not essential. Applicants should write in confidence with full details to Personnel Dept. (ED/205) E.M.I. Eng. Dev. Ltd., Hayes, Middx. W 2587

ENGINEER, aged 25 to 35, preferably having Higher National Certificate, required for the maintenance of electronic equipment and the testing and alignment of new instruments used for quality control and automatic testing of all types of telecommunication cables. Apply giving full particulars to Box No. W 1187.

ENGINEERS required for research and development work on servo-mechanisms. Hydraulic, pneumatic and electrical servos are involved in this work covering such devices as guided missiles, radar scanners, motor control gear and turbo-alternators. Vacancies as follows: (A) Theoretical engineers accustomed to carry out mathematical analysis of servo-systems (Ref. 60). (B) Practical systems engineers capable of directing original work in all above fields (Ref. 61). (C) Assistant grades to work under direction of systems engineers on development work (Ref. 62). Candidates for (A) and (B) should possess Honours Degree with some practical experience or have had some previous practical experience in similar work. Candidates for (C) should be mechanical engineering or electrical engineering graduates or students. Knowledge of electronics of great value in this work. Write in detail, quoting reference number of position sought, to: The Personnel Manager (Technical Employment), de Havilland Propellers Limited, Hatfield, Herts. W 2434

ENGINEER REQUIRED for operational tests, maintenance and development of Airborne Electronic equipment. Degree, H.N.C., or equivalent, with some practical experience of electronic equipment desirable, must be British or Commonwealth subject. Apply: Construction Department, British Thomson-Houston Co., Ltd., Rugby. W 2607

ENGINEERS, TECHNICAL ASSISTANTS are required at all grades for work on valve development, valve pre-production and electronic engineering. Minimum qualifications, H.N.C. or B.Sc. for Senior positions and O.N.C. or inter for Junior. Whenever possible company offers promotion from within and salaries reviewed regularly. Write: Personnel Officer, The M.O. Valve Co. Ltd., Brook Green, Hammersmith, London, W.6. W 1151

ENGLISH ELECTRIC CO. LTD., Stafford, have vacancies in their Instrument Division for Sales and Contracts Engineers, preferably with H.N.C. or O.N.C. and some experience in this field. Good prospects of future outside representation. The positions offered are permanent, progressive and pensionable. Reply, in confidence, and quoting reference 1175E, to Dept. C.P.S., 336/7, Strand, W.C.2. W 2613

ERICSSON TELEPHONES LTD., have in their Research Laboratories a number of vacancies for circuit designers and equipment engineers to work on nucleonic instruments, and interesting new developments in electronic computing and switching; both senior and junior posts are available. Applicants should have a degree or equivalent plus several years' experience of appropriate work for the senior posts; correspondingly reduced qualifications and experience will be accepted for junior posts. Salaries will be in accordance with age, qualifications and experience. Applications, giving details of age, academic or other training and qualifications, experience, and starting salary required, should be sent to the Personnel Officer, Ericsson Telephones Ltd., Beeston, Nottingham. W 197

EXPERIENCED FAULT-FINDERS wanted by Midland Manufacturers of radio equipment. Permanent posts located in the Midlands are offered to men with experience of Radar, Radio Control, V.H.F. Equipment. Write stating fully experience and salary required to the Personnel Manager. Box No. W 2439.

EXPERIENCED Radio Testers and Inspectors required for production of communication and radio apparatus. Also Instrument makers, wirer and assemblers for Factory Test apparatus. Apply Personnel Manager, E. K. Cole Ltd., Ekco Works, Malmesbury, Wilts. W 146

EX-SERVICE RADIO-RADAR MECHANICS. A leading company in the Electronic field has vacancies for men interested in Manufacture and Maintenance of Radar Equipment. Opportunities occur in the factory and in the outside maintenance field for men who have had Service training and some theoretical knowledge. Applicants should write giving full details of their experience, etc., to Box No. W 2437.

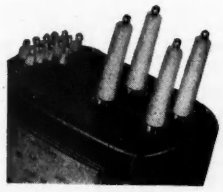
FERRANTI LTD., Wythenshawe, have a number of vacancies for Technical Assistants in the following fields of investigation: Hydraulic control mechanisms and servos, gyros, relays and electro-mechanical instruments, experimental vibration testing, microwave systems, R.F. circuits, pulse circuits. Applicants should hold a degree or Higher National Certificate in Electrical or Mechanical Engineering. The work would be of particular interest to men completing National Service in technical branches of the Services. The appointments would be to the permanent staff of the company and offer the prospect of interesting work in modern well-equipped laboratories opened in South Manchester within easy reach of residential districts. The company operates a Staff Pension Scheme. Application forms from Mr. T. J. Lunt, Staff Manager, Ferranti Ltd., Hollinwood, Lancs. Please quote reference WTA. W 2413

CLASSIFIED ANNOUNCEMENTS
continued on page 6

One thing leads . . .

. . . not to another but to success. A formula second to none in the world of industry is : " Do one thing only and do it well." Many great organisations have been founded and have flourished on the application of this principle.

So Parmeko, who devote all their enthusiasm, enterprise, and energy to making transformers, cannot claim to have thought of something new; they do profess, however, to apply every up-to-date method to help them do their job well—so successfully, in fact, that with some great manufacturers of electronic and electrical equipment the name Parmeko is synonymous with the best transformers.



The firm with the one-track mind

PARMEKO *of* **LEICESTER**

MAKERS OF TRANSFORMERS *for the Electronic and Electrical Industries*

SITUATIONS VACANT (Cont'd.)

The engagement of persons answering these advertisements must be made through a Local Office of the Ministry of Labour or a Scheduled Employment Agency if the applicant is a man aged 18-64 inclusive or a woman aged 18-59 inclusive unless he or she, or the employment, is excepted from the provisions of the Notification of Vacancies Order, 1952.

FERRANTI ELECTRONIC COMPUTORS. Ferranti Ltd. (Computor Dept.), Moston, Manchester, have the following vacancies. (1) Senior Engineers for Research and Development work on large-scale electronic computing equipment. Qualifications: First- or good second-class Honours Degree in electrical engineering with previous experience of development work in electronics or with electrochemical devices. Ref. D.C.S.E. (2) Engineers for the commissioning section and for maintenance of computing equipment. Qualifications: For senior posts a Degree in electrical engineering and for the more junior approximately H.N.C. standard but more essentially experience with electronic circuitry and test equipment. Ref. D.C.M.F. Permanent Staff appointments with Pension Benefits. Application forms from Mr. T. J. Lunt, Staff Manager, Ferranti Ltd., Hollinwood, Lancs. Please quote appropriate reference. W 2578

GRADUATES with an Honours Degree in Physics or in Electrical Engineering are required by the British Thomson-Houston Co. Ltd., Rugby, for research in the field of High Power Ultra High Frequency Valves. Applicants should write to the Director of Research giving their age, qualifications and College, quoting reference DR. W 2483

GRADUATES WITH HONOURS Degrees in Physics or in Electrical Engineering are required by the British Thomson-Houston Co., Ltd., Rugby, for research in the field of Thyratron development; some knowledge of electronics is desirable. Applicants should write to the Director of Research, giving their age, qualifications and College, quoting the reference K.B. W 2591

GRADUATES with Honours Degrees in Physics or in electrical engineering are required by the British Thomson-Houston Co. Ltd., Rugby, for research in the field of Klystron development; some knowledge of electronics is desirable. Applicants should write to the Director of Research, giving their age, qualifications and College, quoting the reference DR. W 2592

GUIDED MISSILE TEST EQUIPMENT. The following interesting and important vacancies exist in a small but expanding department engaged on the development and use of electronic and electro-mechanical test gear. Specialized training will be given:—Electrical Engineer (ref. E.E./46) to lead a small test and fault-finding team. Applicants should have electronic experience, preferably in one or more of these fields:—servo-mechanisms, analogue computors, radar, micro-wave, pulse, communication or telemetry. Degree or H.N.C. standard essential. Development Engineer (ref. E.E./48). Young graduate required to design and develop electronic and pneumatic test equipment. Hons. electrical engineering Degree essential. Assistant Engineer (ref. E.E./49) to compile inspection test instructions for component and missile testing. Electronic experience essential and should be of H.N.C. standard. These positions offer excellent scope for advancement together with good salary and bonus. Pension Scheme. Send details of experience and qualifications, quoting appropriate reference, to the Assistant Manager, The Fairey Aviation Co. Ltd., Weapon Division, Heston Aerodrome, Hounslow, Middx. W 2596

GUIDED WEAPONS. Vickers-Armstrong Limited, Weybridge, has vacancies for suitably qualified Senior and Junior Technicians, Engineers, Craftsmen in the Electronics, Electrical and Mechanical sections of the Guided Missiles field of research and development. Applications should be made to the Employment Manager, Vickers-Armstrong Limited, Weybridge Works, Weybridge, Surrey. W 2367

HISPANO-SUIZA'S British associate company has a vacancy for an electronic development engineer in connexion with the design and development of close-range gunnery equipment. Appointment entails design office and field work on relay controls schemes, servo-mechanisms, strain gauge recording, etc. Applicants must have engineering Degree or equivalent qualification. The company offers excellent sport and welfare facilities and a voluntary pension and life assurance scheme. Applications with details of age, qualifications, experience and salary required should be sent by post to British Manufacture and Research Co. Ltd., Grantham, Lincs, quoting reference AWK/MF/Staff C. W 1152

INDUSTRIAL TELEVISION. A vacancy exists for a television engineer in the age group 23-35 with a team working on the design of industrial television equipment. Applications giving full details of age, experience and qualifications, should be addressed to the Chief Television Engineer, Pye Radio Works, St. Andrew's Road, Cambridge. W 2498

IN THE RESEARCH DEPARTMENT of Short Brothers & Harland Limited—The Electronics Section has vacancies for Two Senior Research Engineers. The work concerns navigational and servo systems, Guided Missiles and other commercial and service Projects of an interesting and progressive nature. Qualifications: An Honours Degree and at least five years' relevant experience in the development field. These appointments are permanent. The organization is expanding. The prospects and salaries for the right men are inviting; Pension Scheme; Assistance with housing and with removal expenses. Applications, quoting S.A.10, and giving full particulars to "Staff Appointments Officer," P.O. Box No. 241, Belfast. W 2558

JUNIOR DESIGNERS required to deal with small transformers, power, audio, pulse, etc. Specialized training will be given to engineers with suitable basic training and experience. Applications to Technical Director, Gresham Transformers Ltd., Twickenham Road, Hanworth, Middlesex. W 1158

LAURENCE, SCOTT & ELECTROMOTORS LTD., Norwich. Research Department. Senior Engineer required for new Research Laboratory at Norwich. University Degree or equivalent. Successful candidate must be capable of taking charge of projects in some of the following branches of instrument engineering: Analogue Computors; Servos and Control Systems including feedback amplifiers; Instrument type electrical machines; and mechanical instruments. The projects are not generally associated with guided weapons. Salary commensurate with qualifications and experience. Superannuation scheme in force. Applications with full particulars to The Secretary, Laurence, Scott & Electromotors Ltd., Gothic Works, Norwich, Norfolk. W 2569

METROPOLITAN-VICKERS ELECTRICAL CO. LTD., Trafford Park, Manchester 17, have vacancies for servo engineers with some practical experience in Electric servo and control circuit design and application. Qualifications required, a Degree or Higher National Certificate. Applicants should not be less than 26 years of age. The posts are permanent and pensionable. Salary according to qualifications and experience. Apply in writing to The Personnel Manager, marking envelope "Servo Mechanisms." W 2557

MICROWAVE ENGINEER required by Decca Radar Limited to start up and lead a new team to undertake microwave component development. The post will carry a good starting salary with first class opportunities to expand the scope of the group. It is essential that applicants are of British Nationality, have had a sound training in the field, and are personally suitable in character to act as a leader. Pension Scheme. Write quoting ref. RAL/66 to Decca Radar Ltd., 2, Tolworth Rise, Tolworth, Surbiton, Surrey. W 2584

McMICHAEL RADIO LTD., Slough, Bucks, have vacancies from time to time for Electronic Engineers to be engaged on Government projects. Those wishing to be considered are invited to write fully to the Chief Engineer, Equipment Division. W 205

MUIRHEAD & CO. LTD., Beckenham, Kent. Design Draughtsmen. Expanding programme offers vacancies for both senior and junior Design Draughtsmen with experience of light electromechanical apparatus. The work covers a wide range of developments and the positions offer ample scope for persons with initiative and ability. Salary according to qualifications and experience. Apply by letter stating details of age, training and experience to Personnel Manager. W 2605

PHYSICIST with good knowledge of electronics and some industrial experience required by progressive instrument company in Greater London area. This post will appeal to a man who enjoys working for an independent company where there is an atmosphere of enthusiasm and policy is made on the spot. The work is connected with the design of new process control devices and will develop on a large scale. Applicants should have University Degree and be not over 25. Initial salary range £500-£600 per annum. Please write with full details to Box No. W 1198.

PLANNING ENGINEERS required. Applicants should preferably have a press tool background and have had previous experience of process planning of small electrical and mechanical assemblies. These vacancies present attractive opportunities and work of a wide and interesting nature. A good salary will be paid to the selected applicants. Eastern suburbs of London. Please reply, giving full details of qualifications and experience to Box No. W 2589.

PYE TELECOMMUNICATIONS LTD., Cambridge, invite applications from suitably qualified persons for the following immediate vacancies. Planning Engineer, experienced in the layout of H.F. and V.H.F. Radio communications system. Electronic Engineer for the developing of H.F. transmitting equipment. The applicant filling this post will be responsible for the supervision of projects to the production stage and will work under the general direction of the Senior Engineer. Junior Engineers. Duties will include development work on communication equipments in the H.F., V.H.F. and U.H.F. fields. These vacancies will call for men with design experience and with training to Higher National Certificate level. Good working conditions in modern factory with sports, social and canteen facilities. Excellent opportunities for further study. Single accommodation available. Applications, in writing, stating age, qualifications, and experience, should be addressed to the Personnel Manager. W 204

CLASSIFIED ANNOUNCEMENTS
continued on page 8

7-lb. reels

Ersin Multicore 5-core Solder is supplied on nominal 7-lb. reels for factory use in 9 gauges from 10 to 22 s.w.g. Approved by A.I.D., G.P.O., A.R.B., D.T.D. 599, R.C.S. 1,000 and all U.S.A. Federal specifications.

Multicore

Size 1 Carton

For Radio Enthusiasts and Service Engineers in 4 specifications as below:

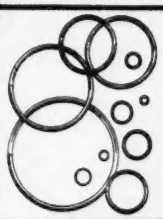
PRICE 5/- EACH (SUBJECT)

Catalogue Ref. No.	Alloy Tin/Lead	S.W.G.	App. L'gth per carton
C 16014	60/40	14	21 feet
C 16018	60/40	18	55 feet
C 14013	40/60	13	19 feet
C 14016	40/60	16	38 feet

Radio & T/V Service Engineers' 1 lb. reel

This is a special economy pack for Service Engineers and Workshops using a good deal of solder, contains approx. 167 ft. of 18 s.w.g. 50/50 alloy Ersin Multicore Solder on a 1-lb. reel. Cat. ref. R5018. 15/- each (subject).

meets every



Solder Rings

Ersin and Arax Multicore Solder is made up into butt jointed rings at no extra cost. Rings ¼" - 2" dia. and 10-22 s.w.g. (according to diameters) supplied from stock; other sizes to special order.

Liquid & Jelly Flux

Ersin Flux is supplied in liquid form for dipping purposes, when cored solder cannot be used. High viscosity red jelly is now available for processes where flux with better properties of adherence is needed. M.O.S. approval for specific purposes. Size 12 tins 4/6 each (subject).

need for

Ultra Fine Gauges

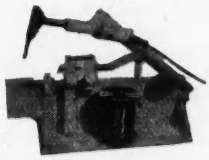
In addition to the 9 gauges (from 10 to 22 s.w.g.) supplied on 1-lb. and 7-lb. reels, Ersin Multicore Solder can now also be supplied to special order in even gauges between 24 and 34 s.w.g. on ½-lb. reels.

Tape Solders

When using Ersin Multicore Solder in tape form, only a match is needed to make a sound joint. Available on 3½-lb. reels for factory use in widths from ⅛"-⅜" and thicknesses from ·005.

everything

Automatic Soldering Head



This machine feeds ⅛" to ⅜" of 13 to 19 s.w.g. Multicore Solder each time the electric iron descends. Supplied with or without motor or for installation to existing drive.

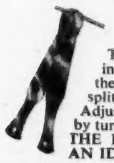
Printed Circuits

A COMPLETE SOLDERING PROCESS HAS BEEN DEVELOPED BY MULTICORE LABORATORIES.

ASK FOR PUBLICATION REF. P.C.L. 100.

that needs

Bib Wire Stripper and Cutter



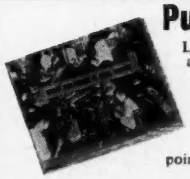
This handy 3-in-1 tool strips insulation without nicking the wire; cuts wire cleanly; splits plastic extruded twin flex. Adjustable to most thicknesses by turning a screw. 3/6 (subject). THE BIB WIRE STRIPPER IS AN IDEAL CHRISTMAS GIFT

Arax Multicore Solder

For all metal fabrications, except aluminium. The non-rosin flux has a residue that can easily be removed with water. 3 alloys, 9 gauges on 7-lb. and 1-lb. reels and 5/- carton in 4 specifications.

soldering

Publications



Laboratory Engineers and Technicians are invited to write (on their firm's letterheading) for the latest edition of *Modern Solders*. Contains data on melting points, gauges, alloys, etc.

Ersin Multicore Solder is now supplied with 5 cores of flux, unless otherwise ordered. Thin solder walls and extra fast flux make this solder suitable for high-speed soldering processes. In many cases economies can be made by using an alloy of lower tin content. Ersin Multicore 5-core Solder is available in a variety of alloys. Different types of flux can be incorporated to suit special processes.

MULTICORE SOLDERS LTD., MULTICORE WORKS, HEMEL HEMPSTEAD, HERTS. (BOXMOOR 3636)

SITUATIONS VACANT (Cont'd.)

The engagement of persons answering these advertisements must be made through a Local Office of the Ministry of Labour or a Scheduled Employment Agency if the applicant is a man aged 18-64 inclusive or a woman aged 18-59 inclusive unless he or she, or the employment, is excepted from the provisions of the Notification of Vacancies Order, 1952.

PHYSICISTS. A vacancy is available for a Physicist holding a Ph.D. Degree, and having practical experience, for work on the production of power from atomic energy, and to be employed initially at Harwell, age 30-35. A vacancy is also available for an Assistant to the above, age 26-30. Good salaries will be paid to men holding the necessary qualifications. Box No. W 1205.

PRODUCTION ENGINEERS required by a large engineering organization situated in the London area. Applications are invited from men with appropriate engineering qualifications and experience in the electronic engineering fields. The successful candidates will have extensive experience of administration, tool design, estimating and time motion study, and will be acquainted with the most up-to-date production methods and techniques. They will have experience of small batch production of electronic equipment and/or light electro-mechanical precision instruments. For men with the required qualifications, initiative and drive these vacancies provide excellent prospects in a rapidly expanding organisation. Please write, in strictest confidence, giving full details of experience to Box No. W 2525.

PRODUCTION ENGINEER required to organise the manufacture of wire-wound resistances. Wide experience essential. This is a new department of an existing company offering considerable scope for early advancement. Box No. W 1212.

PROJECT ENGINEERS are required to take charge of microwave electronic and mechanical developments in connection with guided weapon and other applications in a company near London. Candidates should be graduates between the ages of 30 and 40. Salaries range from £1,000 upwards according to age and experience. Pension scheme in operation. Full particulars, which will be treated in confidence, should be addressed to Box No. W 2601.

RADIO AND ELECTRICAL Department of British Company operating in Central Africa require experienced man. Qualifications include expert radio knowledge, practical repair and maintenance of refrigerators domestic appliances, etc.; and Salesmanship. Four years' contract with passages. Housing, paid leave, etc., etc. Commencing salary according to experience. Pension scheme; low income tax; healthy climate. Write 2602, Wm. Porteous & Co., Glasgow. W 2573

RADIO AND RADAR TESTERS. First class men required for work on V.H.F. Communication Equipment by Midland Manufacturers. Men with wide experience of Fault Finding in any of the fields mentioned should write giving full details to Box No. W 2438

RADIO ENGINEER required, experienced in design and development of mobile radio equipment. Small progressive firm near Southampton. State qualifications, experience and salary expected. Box No. W 207.

REQUIRED keen young Engineer or Physicist (completed National Service) for interesting work on scientific and industrial instruments employing servo mechanisms and electronic techniques. Technical education to level of H.N.C. with sound knowledge of basic electrical and magnetic principles and willingness to learn. Good salary and excellent prospects for the right man. Write giving full details to W. G. Pye Ltd., Granta Works, Newmarket Road, Cambridge. W 2604

RESEARCH ENGINEER required for work on magnetic and allied materials. Good salary and prospects. Write giving details age, qualifications, experience and salary required to Personnel Manager, Telephone Manufacturing Co. Ltd., Sevenoaks Way, St. Mary Cray, Kent. W 2563

RESEARCH ENGINEER OR PHYSICIST required to undertake research and technical control in connection with the manufacture of wire-wound resistances. Good technical education and experience in this field essential. This is a new department of an existing company offering considerable scope for advancement. Box No. W 1213.

SALES MANAGER—Progressive Company of National repute, designers and manufacturers of a wide range of communication equipment, seek the services of a Sales Manager. Essential requirements include a knowledge of the communication market and the proven ability to organise and promote sales. The post is at high executive level and remuneration will be scaled to the individual's qualifications and results. All applications will be treated as confidential. Write Box No. W 1211.

SENIOR DESIGN ENGINEER required for Television and Radio development work. Experience and ability to work on own initiative essential. Knowledge of modern production requirements an advantage. Salary according to experience and ability. Pension Fund. Junior Lab. Engineers also required for progressive posts. Apply giving details to Personnel Manager, Pilot Radio Ltd., Park Royal Road, N.W.10. W 1199

SENIOR ELECTRONIC DESIGN ENGINEER required for very interesting work applying electronics to industrial process control problems. Experience of electrical servo mechanism essential together with a good basic knowledge of electronic circuit techniques. This post offers considerable scope for advancement. A knowledge of the requirements for instrumentation and control in industries such as oil refining, iron and steel and chemical plants would be an advantage though not essential. Apply giving full details to Personnel Manager, Elliott Bros. (London) Ltd., Century Works, Lewisham, S.E.13. W 2609

SENIOR ELECTRONIC DESIGN ENGINEER required to undertake interesting development of instruments concerned with strain measurement and its application to industrial weighing and loading control. Previous experience in design of electronic low frequency measuring equipment desirable together with a good fundamental knowledge of servo mechanism. Candidates should have a keen interest in applying electronics to industrial applications and possess a degree or equivalent qualifications. Apply giving full details to Personnel Manager, Elliott Bros. (London) Ltd., Century Works, Lewisham, S.E.13. W 2612

SENIOR ELECTRONIC DEVELOPMENT ENGINEER required by progressive company, laboratories Central London, for television and radio receiver circuit development. Experience in these fields is essential, special experience in time base and tuner development an advantage. Applicants should be capable of working with the minimum of supervision. Salary commensurate with experience. Reply in confidence stating qualifications and experience to Box No. W 1185.

SENIOR PHYSICISTS AND ENGINEERS are invited to write to the Research Director of Decca Radar Limited, regarding the opportunities which exist in this Company owing to the continual expansion of its activities in the field of navigational aids and communication. Senior posts available are on a very substantial salary scale and there are excellent prospects of higher appointment for men of proven ability. British Nationality is essential. A Pension Scheme is in operation. Letters giving full personal data should be addressed to the Research Director, Decca Radar Limited, 2 Tolworth Rise, Surbiton, quoting reference RLA/47. W 2646

SENIOR TRANSFORMER DESIGNER required with experience of all types of transformers up to 3 000 kVA. Excellent prospects for an energetic man capable of supervising iunior engineers. Excellent working conditions, Pension Scheme, Canteen, etc. West London area. Applications to Box No. W 1157.

SHORT BROTHERS & HARLAND LIMITED, have a vacancy in their Research Department for a Mathematician to undertake the theoretical investigation of automatic controls, navigational systems, etc. Applicants must possess an Honours Degree. Some experience of electronic or instrument systems would be an advantage. Good salary and prospects in a rapidly expanding organisation. Pension Scheme; assistance with housing and with removal expenses. Send full particulars of age, qualifications and experience to Staff Appointments Officer, P.O. Box No. 241, Belfast, quoting S.A.12. W 2572

SHORT BROTHERS AND HARLAND LIMITED require an Engineer to promote the sale of electronic computing equipment. Applicants must possess initiative and personality, while a knowledge of analogue computing techniques or electronics is desirable. The appointment will be in London, but will involve travelling for liaison with customers, and with the Company's Development Laboratories. Send details of age, experience and salary required to Short Brothers and Harland Limited, P.O. Box No. 241, Belfast. W 2536

SIR W. G. ARMSTRONG-WHITWORTH AIRCRAFT LTD., Baginton, Nr. Coventry. Guided Weapons. There are vacancies for the following Technical Staff for work on Guided Missiles: Electronic Engineers with experience of research and development work on radar, television or similar fields, and preferably with Service experience. A University Degree or similar qualification is essential. Required to undertake research and engineering development on various forms of communication systems and for work connected with the overall electrical design of guided missiles. W 2404

TECHNICAL/COMMERCIAL ENGINEER required by electrical manufacturers in Eire for their Radio Department. Candidates should be between the ages of 25/40 and must have technical experience applied to radio receivers and amplifiers. Candidates, who will be interviewed in London, should write giving age and full details of technical and educational qualifications, previous experience and salary required to Box No. W 2571.

TECHNICAL COMMERCIAL REPRESENTATIVES who have experience of the applications of high grade electronic test equipment and are qualified in electronics, are invited to apply for appointments with Solartron Electronic Group, Queens Road, Thames Ditton, Surrey. W 2595

TECHNICAL STAFF required for the large new "B & R" Relay Factory, shortly opening at Harlow, Essex, including Sales Engineers, Experimental Engineers, etc. Relay experience not necessary but a good knowledge of the fundamentals of electricity and physics essential. Houses will be made available. Besson & Robinson Ltd., Kidbrooke Park Road, S.E.3. Lee Green 8541 Ext. 20. W 1206

TECHNICIAN required by the General Electric Co. Ltd. for installation and maintenance of H.F. equipment at their Wembley Works. Applicants should have had previous experience in this type of work and be prepared to travel in this country. Preference will be given to those who have obtained their O.N.C. in electrical engineering or the equivalent and are not over 26 years of age. Apply in writing quoting reference P.H. to the Staff Manager, Magnet House, Kingsway, W.C.2. W 2553

TECHNICIAN with experience in electronic work required for development laboratory in large Telecommunication Engineering Works, London area. Give particulars of experience, education and technical training, qualifications and commencing salary required. Box W 2582.

1. TECHNICIANS. Several vacancies are available for technicians and men having design experience and holding 1st Class Honours Degree in Mechanical Engineering and having practical experience preferably in Marine Engineering or alternatively experience on the Mechanical side for the generation of power for land purposes. They are required for work on the production of power from atomic energy, and will be employed initially at Harwell. Age 27-35. Good salaries will be paid to men holding the necessary qualifications. 2. Draughtsmen. Several vacancies are available for draughtsmen holding Higher National Certificates for work on the production of power from atomic energy. Work would be initially at Harwell. Age 30 or over. Good salaries will be paid to men having the necessary experience. 3. Senior Project Engineer. A vacancy is available for a Senior Project Engineer to head a group for the production of power from atomic energy. Applicants should have a background of experience, preferably in Marine Engineering, or alternatively experience on the Mechanical side of the generation of power for land purposes. In

CLASSIFIED ANNOUNCEMENTS
continued on page 10

Give your products the advantages of military experience with...

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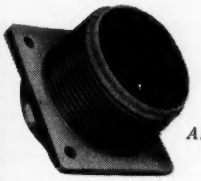
AN3106B PLUG



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"AN" (Air Force-Navy) Connectors were pioneered by Cannon and the armed services in the interests of standardization, efficiency and economy. Since the first "AN" specification appeared in 1939, Cannon Electric has continued to work closely with all branches of the service, improving and expanding the "AN" Series to meet the ever-increasing demands placed upon them by technical advances in all engineering fields. Today, there is an "AN" Series Connector to meet the needs of practically every environmental condition. Designed, tooled, and manufactured in one plant by technicians and artisans of long experience. You'll find Cannon "AN" Connectors . . .

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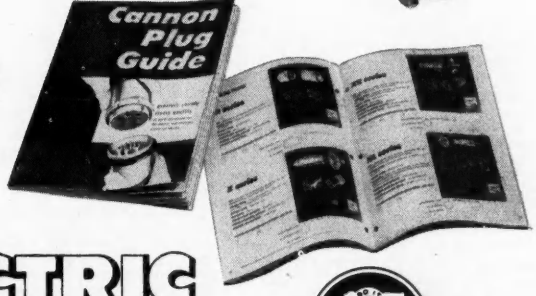
Contains history, application, classification, insert arrangements available, "how to select," all technical details of Cannon Connectors.



CANNON ELECTRIC

CANNON ELECTRIC CO. (Gt. Britain) LTD., 138, Wardour Street, London, W.1.

Factories in London, Paris, Los Angeles, East Haven, Toronto, Melbourne.

SITUATIONS VACANT (Cont'd.)

The engagement of persons answering these advertisements must be made through a Local Office of the Ministry of Labour or a Scheduled Employment Agency if the applicant is a man aged 18-64 inclusive or a woman aged 18-59 inclusive unless he or she, or the employment, is excepted from the provisions of the Notification of Vacancies Order, 1952.

addition, applicants should have scientific qualifications in the form of 1st Class Honours Degree in Marine or Mechanical Engineering and should for preference be in the range 35-40. Good salary will be paid to a man meeting the stated requirements. Employment will be at Harwell initially. Box No. W 1203.

TEST ENGINEER for small section testing nucleonic instruments. Good theoretical knowledge and practical experience of ratemeters, counters, amplifiers, etc., essential. The work entails the production of test schedules, the specification of suitable test gear, and testing and fault finding of small production quantities. Write giving full details of previous experience to: Test Room, General Radiological, Ltd., 18, New Cavendish Street, W.1. W 1153

TEST SUPERVISOR required for Production Test Department of Electronic Instrument manufacturer situated in the West of England. Candidates for this post should possess administrative ability and sound knowledge of small transformer theory and audio frequency measurement. A knowledge of servo mechanisms would be an advantage. Salary will be commensurate with responsibilities involved and housing assistance may be provided for suitable married applicant. Apply Box No. TS1. W 1204.

TEST GEAR DESIGN ENGINEERS and Maintenance Engineers required with practical experience of this class of work, based on sound knowledge of electronic principles. These vacancies are permanent and progressive. A company pension scheme in operation. London area. Please write, in confidence, giving full details of qualifications to Box No. W 2588.

THE EDISON SWAN ELECTRIC CO. LTD. require a Service Engineer for installation and servicing in the field of their electro-medical equipment. Please send details of experience and salary required to 155 Charing Cross Road, W.C.2, Ref: Electro/Med. W 2583

THE ENGLISH ELECTRIC CO. LTD., Guided Weapons Division, Luton, has vacancies for all grades of Senior and Junior staff in the Electronics Department as follows:—Senior Engineer—with experience of production engineering of prototype electronic equipment and a working knowledge of electronic circuitry. Senior Engineer—for work on circuit development, and a sound fundamental knowledge of Electronics. Senior Engineer—with a wide experience of radar and communications equipment maintenance. Senior Instrumentation Engineers—with Degree or H.N.C. and experience of the design of transducers for use with electronic or bridge measuring systems. Section Leader—to supervise a team of designers and draughtsmen engaged on electronic equipment. Must be familiar with all aspects of RCS.1000. Senior Designer Draughtsman—to undertake preliminary design of special electronic equipment associated with guided missiles. Draughtsmen—for Detail Design of specialized electronic or electromechanical equipment, and of electrical and electronic laboratory test equipment. Draughtsman Checker—for work on production drawings of electronic and electromechanical equipment. Must have previous design experience. Circuit Draughtsman or Woman—for the preparation of circuit and wiring diagrams for electronic equipment, and with a keen interest in Electronics and a good knowledge of components. These are permanent and progressive posts, and attractive salaries are offered to the right men. Staff Pension after qualifying period. Applications to Dept. C.P.S., 336/7, Strand, W.C.2., quoting Ref. 1164D. W 2614

THE EDISON SWAN ELECTRIC CO. LTD. have the following vacancies in their Special Products Development Laboratory:—(1) Engineer in charge. Engineering Degree, or equivalent, with experience of developing electronic equipment ready for factory production. (2) Engineers able to do original electronic and mechanical development work. The work of the Laboratory includes development of a wide range of industrial and medical electronic apparatus and instruments. Please write stating experience, age and salary required, to 155, Charing Cross Road, London, W.C.2. Reference S.P. Lab. W 2603

THE ENGLISH ELECTRIC CO. LTD., Guided Weapons Division, Luton, has vacancies for all grades of Senior and Junior Staff in the Electronics Department as follows: Senior Engineer—with experience of production engineering of prototype electronic equipment and a working knowledge of electronic circuitry. Senior Engineer—for work on circuit development, and a sound fundamental knowledge of Electronics. Senior Engineer—with a wide experience of radar and communications equipment maintenance. Senior Instrumentation Engineers—with Degree or H.N.C. and experience of the design of transducers for use with electronic or bridge measuring systems. Section Leader—to supervise a team of designers and draughtsmen engaged on electronic equipment. Must be familiar with all aspects of RCS. 1,000. Senior Designer Draughtsman—to undertake preliminary design of special electronic equipment associated with guided missiles. Draughtsmen for Detail Design—of specialized electronic or electromechanical equipment, and of electrical and electronic laboratory test equipment. Draughtsman Checker—for work on production drawings of electronic and electromechanical equipment. Must have previous design experience. Circuit Draughtsman or Woman—for the preparation of circuit and wiring diagrams for electronic equipment, and with a keen interest in Electronics and a good knowledge of components. These are permanent and progressive posts, and attractive salaries are offered to the right men. Staff Pension after qualifying period. Applications to Dept. C.P.S., 336/7 Strand, W.C.2. quoting Ref. 1164B. W 2554

THE GENERAL ELECTRIC CO. LTD., Brown's Lane, Allesley, Coventry, requires Mechanical Development Engineers, Designer-Draughtsmen and Draughtsmen, preferably with experience of Radar type equipments for work on Guided Weapons and like projects. Also required, Senior and Junior Electronic Development Engineers, particularly in the field of Microwave and Pulse Applications. Salary according to age, qualifications and experience. Apply by letter stating age and experience to the Personnel Manager. Ref. R.G. W 208

THE MULLARD RADIO VALVE CO. LTD. require an Electronic Engineer to design and supervise the construction of experimental test gear for colour television cathode ray tubes. Applicants who possess a B.Sc. Hons. Degree and have an interest in advanced circuitry techniques are particularly invited to apply. This vacancy is caused by the expansion of the Company's activities in this field. Commencing salary will be according to individual age, experience and qualifications and can be considered as progressive. The Company's policy regarding the employment of scientific staff provides adequate prospects for advancement. There are facilities for further study and a Company Pension Scheme and progressive holiday plan. Applications in writing will be treated with the strictest confidence and should be addressed to The Personnel Officer, The Mullard Radio Valve Co. Ltd., New Road, Mitcham Junction, Surrey, quoting reference JFG/A.1/L.7. W 2566

THE MULLARD RADIO VALVE CO. LTD. require a Physicist or Electrical Engineer for its Cathode Ray Tube Department. The successful candidate will be expected to carry out investigations and experiments in production techniques, materials and manufacturing equipment. The main emphasis will be upon manufacturing rather than development work Applications are invited from Physicists or Engineers possessing a B.Sc. Degree or equivalent qualifications and previous experience is not essential. The vacancy outlined above is caused by the expansion of the Company's activities in this field. Commencing salary will be according to individual age, experience and qualifications and can be considered as progressive. The Company's policy regarding the employment of scientific staff provides adequate prospects of advancement and breadth of outlook is assured by opportunities for transfer to other fields of work within the Company. There are facilities for further study and a Company Pension Scheme and progressive holiday plan. Applications in writing will be treated with the strictest confidence and should be addressed to The Personnel Officer, The Mullard Radio Valve Co. Ltd., New Road, Mitcham Junction, Surrey, quoting reference JFG/A.1/M.P.4. W 2567

THE MULLARD RADIO VALVE CO. LTD., require a Physicist or Electrical Engineer for design and development work on cathode ray tubes for colour television. Physicists or Engineers who possess a B.Sc. Honours Degree and have an interest in electron optics, glass technology or physical chemistry are particularly invited to apply. The vacancy outlined above is caused by the expansion of the Company's activities in this field. Commencing salary will be according to individual age, experience and qualifications and can be considered as progressive. The Company's policy regarding the employment of scientific staff provides adequate prospects for advancement and breadth of outlook is assured by opportunities for transfer to other fields of work within the Company. There are facilities for further study and a Company Pension Scheme and progressive holiday plan. Applications in writing will be treated with the strictest confidence and should be addressed to The Personnel Officer, The Mullard Radio Valve Co., Ltd., New Road, Mitcham Junction, Surrey, quoting reference JFG/A.1/M.D.2. W 2568

THE PLESSEY COMPANY LIMITED needs Engineering Personnel to staff its newly formed Radar and Electronics Laboratories situated at Manor Way, Boreham Wood, Herts. Radar and electronic circuit engineers. Radar and electronic technical writers (preferably with knowledge of components and specifications in this subject). Draughtsmen (Male or Female). Technical Shorthand-typists, Instrument Makers. Will those interested in well-paid permanent and progressive positions in these fields write to Mr. J. Rhys-Jones, at the above address. W 2600

THE VICKERS-ARMSTRONGS RESEARCH AND DEVELOPMENT Establishment have immediate vacancies as follows: Junior Technicians who have completed their National Service, hold an Honours Degree in Mechanical Engineering and desire to make their future in the development of prototype machinery. Test Engineers who have completed their National Service, hold a Pass Degree or Honours in Mechanical Engineering together with a knowledge of Electronics. Applications stating qualifications, experience and salary required should be addressed to the Labour Manager, Vickers-Armstrongs Limited, Barrow-in-Furness, Lancs. W 2546

TRANSFORMER DESIGNER required for development projects involving audio-frequency power transformers, pulse transfomers, oil-filled units, etc. Apply stating age, qualifications and experience to the Personnel Manager (Ref. R.G.), The General Electric Co., Ltd., Brown's Lane, Allesley, Coventry. W 192

TWO TECHNICAL AUTHORS vacancies exist in the Technical Publications Department of Smiths Aircraft Instruments Limited, Bishops Cleeve, Cheltenham, Glos., one author being required for work on general electrical and mechanical instruments and the other for work on electronic instruments, automatic pilots, etc. The qualifications required are the ability to write clear concise English, combined with a sound electrical and mechanical background. Please write giving details of age, experience, and salary required to the Personnel Manager, Smiths Aircraft Instruments Ltd., Bishops Cleeve, Glos., quoting reference 39/EN. W 1150

CLASSIFIED ANNOUNCEMENTS
continued on page 12

ACRU—PYROBIT PRODUCTS

ARE FULLY GUARANTEED AND JUST THE JOB FOR THE ELECTRONIC ENGINEER

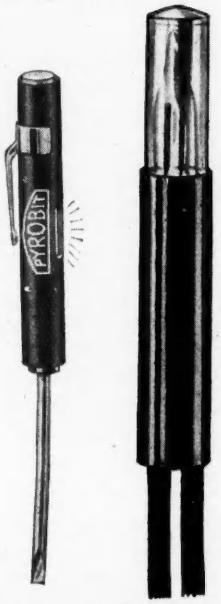
The **PYROBIT** wireless model soldering iron has a new improved long life element and is the lightest iron of its size.

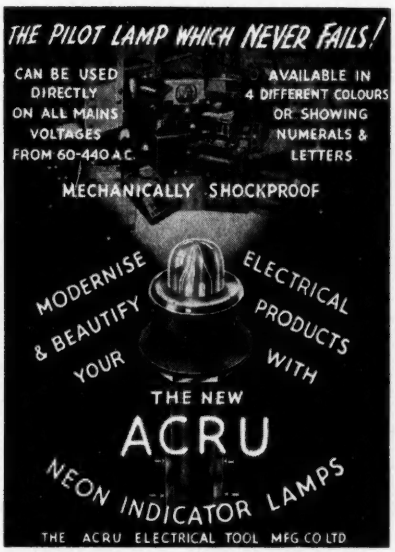
The **PYROBIT** instrument model soldering iron is the most comfortable iron in use and can be conveniently placed on the bench without burning it.

The ACRU L.V. Iron

Can be supplied for voltages of 6, 12 & 24, with or without Transformers. With 10 watts only it reaches the soldering temperature in only 1½ min. The core is made of stainless Steel, thus avoiding corrosion.

PYROBIT pocket Neon testers are the most sensitive on the market. Ideal for speedy fault finding.

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MECHANICALLY SHOCKPROOF
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THE NEW
ACRU
NEON INDICATOR LAMPS
THE ACRU ELECTRICAL TOOL MFG CO LTD

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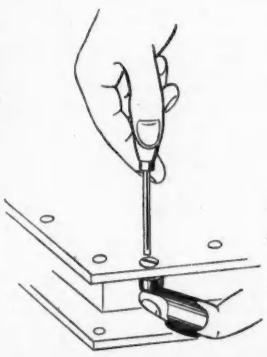
There are 12 different models of ACRU Neon indicator lamps. Over ¼ million already supplied without one complaint about short life.

ACRU—finger tools are a boon for service and production Engineers. They are made for 0,2,4 & 6 B.A. Screws and Nails.



SITUATIONS VACANT (Cont'd.)

The engagement of persons answering these advertisements must be made through a Local Office of the Ministry of Labour or a Scheduled Employment Agency if the applicant is a man aged 18-64 inclusive or a woman aged 18-59 inclusive unless he or she, or the employment, is excepted from the provisions of the Notification of Vacancies Order, 1952.

ULTRA ELECTRIC LIMITED, Western Avenue, Acton, London, W.3, have the following vacancies for electronic engineers in their new Research and Development Laboratories: (1) Senior electronic engineers with Degree or equivalent qualifications with experience, for interesting work in connection with (a) subminiaturization of UHF and VHF circuitry (b) transistor applications in all fields (c) radar and radio navigation equipments. (2) Junior engineers up to intermediate or HNC standards. (3) Test equipment development engineers with experience of design for test equipment concerned with the above. Please write, in strict confidence, to the Personnel Manager, address as above, for an interview appointment. W 2597

ULTRA ELECTRIC LIMITED, Western Avenue, Acton, London, W.3. Radio and Television Development Engineers. (a) Applications are invited from Senior Development Engineers with experience and Academic Qualifications for important work on new development projects. The posts are permanent and pensionable and offer scope for the right men to work in ideal conditions in modern, well-equipped Laboratories. Please write in strict confidence to the Personnel Manager for an interview appointment. (b) Junior Engineers (aged 21/29) are also required, and applicants for these posts should have some technical training and preferably previous experience. Please write as above. W 2500

ULTRA ELECTRIC LIMITED, Western Avenue, London, W.3. Electronic Development Engineers are required in all grades for work on (a) subminiaturization of V.H.F., radio and audio circuitry, (b) transistor applications, (c) V.H.F. communication, (d) pulse techniques, (e) radar and radio navigation. Applications are invited from (a) Senior Development Engineers with Degree or equivalent qualifications, and more than five years' experience in one or more of the above fields. (b) Junior Engineers with Degree or H.N.C. with or without experience for work in the above fields. (c) Test Equipment Development Engineers with experience of design of test equipment to meet production requirements. The posts are permanent and pensionable, and offer scope for the right men to work in ideal conditions in modern, well-equipped Laboratories. Please write in strict confidence to the Personnel Manager for an interview appointment. W 2501

URGENTLY required, young single men as electronic wiremen, assemblers and fitters, also junior and senior Test Engineers in connection with television cameras and ancillary equipment. Apply in writing to Personnel Officer, Dept. 24, Pye Ltd., Radio Works, Cambridge. W 2482

VACANCIES with housing accommodation. Engineers of Higher National Certificate or degree standard and Students of Ordinary National standard are required at our Hemel Hempstead factory for development work on servo-mechanisms and magnetic amplifiers. Previous experience is desirable but not essential; applicants with suitable background and interested in this work should apply. Vacancies also available for Mechanical Designers acquainted with this type of work. Prospects of promotion are excellent in this new and expanding laboratory. Suitable applicants will have the opportunity of renting a modern house or flat in the New Town. Write, as fully as possible, stating your age, experience, to: Dept. B., Box No. W 2520.

VACANCIES EXIST in the Research Laboratory of the British Thomson-Houston Co., Ltd., Rugby, for engineers to work on germanium devices. Applicants should write to the Director of Research giving their age, qualifications and salary required, quoting reference THK. W 2577

V.H.F. RADIO LINK ENGINEER required for the maintenance of 2 Multi-channel links. Previous telephone and radio experience essential. Apply, giving full details of experience, etc., to Personnel Manager, Pye Telecommunications Ltd., Ditton Works, Cambridge. W 1201

W. H. SANDERS (ELECTRONICS) LTD., Stevenage, Herts. Vacancies exist in our Development Section for qualified Electronics Engineers to work on the design of: (i) Microwave instruments and components. (ii) Industrial electronic equipment including servo systems using magnetic amplifiers. (iii) Radar equipment. Qualifications should include relevant experience and preferably a good University degree or equivalent. The salary scales cover the range £500-£1,300 per annum and a generous pension and life insurance scheme is in operation. Expansion of the laboratories in the Company's new premises will provide good opportunities for advancement. Successful applicants may be eligible for housing assistance. Applications giving details of education and career, should be addressed to the Chief Development Engineer. W 1186

WIREMEN required for the laboratory of an engineering company situated in the East London area. Applicants should have had previous experience of electronic computors and ancillary equipment. These are staff appointments and a good salary will be paid to the selected candidates. Please reply giving details of past experience to Box No. W 2590.

WODEN TRANSFORMER CO. LIMITED. require an experienced designer for small Audio and Power Transformers, up to 1 kVA. Good wages plus bonus and pension scheme applies. Apply to Moxley Road, Bilston, Staffs, with full particulars. W 1200

YOUNG GRADUATES completing their National Service are invited to apply for research and development posts in a new and expanding Electronic Tube Laboratory. Comprehensive training at attractive starting salary, and excellent opportunities for a progressive career. Please write for further details to the Personnel Officer, Ericsson Telephones Limited, Beeston, Nottingham. W 2415

Further 'Situations Vacant' advertisements appear in display style on pages 105, 111, 117, 119, 120 and 123.

FOR SALE

AUDIO GEN. 10 c/s-200 kc/s 1 per cent attenuator, perfect, £7 10s. R.F. Sig. Gen. 0·1-35 Mc/s within ½ per cent, attenuator, range SW., etc.: £6 15s. Tape recorder Amplifier complete with oscillator and power. Unused, only £8. All above guaranteed makes, as new. SAE details. Box No. W 1160.

GERMANIUM DIODES 1s. each. Quantities cheaper. BDC, 591 Green Lanes, London, N.8. W 1178

I.E.E. JOURNALS Pt. 1 from Feb. 46, Pt. 2 from Dec. 49, Pt. 3 from Sept. 45. Offers. Vernon, 45 Guildford Road, Farnborough, Hants. W 1193

MAGSLIPS at 1/10th to 1/20th of List Prices. Huge stocks. Please state requirements. K. Logan, Grove Road, Hitchin 1744, Herts. W 183

MAGSLIPS, SELSYNS and many other items connected with automatic and remote control mechanisms are marketed by Servo & Electronic Sales Ltd. Brochure available on request. See our display advertisement on page 120. W 202

METALWORK. All types cabinets, chassis, racks, etc., to your own specifications. Philpott's Metal Works Ltd. (G4BI), Chapman Street, Loughborough. W 2294

SINE-COSINE RESOLVERS (3 in. Magslip Transmitters No. 5, AP 10861). Brand new, each in maker's tin. Offered in quantity at less than one tenth of cost. Export inquiries invited. P. B. Crawshay, 166 Pixmore Way, Letchworth, Herts. W 153

STAINLESS STEEL BALLS, Phosphor Bronze and Brass Balls, Miniature Balls and Bearings; prompt delivery. Insley (London) Ltd., 21/22 Poland Street, London, W.1. Tel. GERrard 8104 and 2730. W 1177

WANTED

COPIES of Electronic Engineering for January, February, April and June 1954. Box No. W 2575.

SERVICE

MACHINE ENGRAVING and **Dividing** on metals and plastics. Good delivery. Parco Works, Albion Road, Horsham. Telephone: HORsham 2273. W 1155

TRANSFORMER & TRANSDUCTOR Development work undertaken. Small electronic types and up to 50 kVA. Avis & Baggs Ltd., Gosbrook Road, Caversham, Reading. W 2560

WEBB'S SERVICE DEPT. for complete renovation of complex communication receivers of any make. Test report issued showing sensitivity selectivity, signal/noise equal to, or better than, maker's original figures. Webb's Radio, 14 Soho Street, London, W.1. W 196

AGENCIES

BRITISH ENGINEER/PHYSICIST now resident in Canada contemplates opening agency for specialized equipment, and wishes to contact manufacturers interested in placing their products in Canada. Box No. W 1197.

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FREE Brochure giving details of courses in Electrical Engineering and Electronics, covering A.M.Brit.I.R.E., City and Guilds, etc. Train with the Postal Training College operated by an Industrial Organisation. Moderate fees. Dept. EE29, E.M.I. Institutes, London, W.4. W 190

T.V. AND RADIO—A.M.Brit. I.R.E., City & Guilds, R.T.E.B. Certificate, etc., on "No Pass—No Fee" terms. Over 95 per cent successes. Details of Examinations and Home Training Courses in all branches of Radio and T.V. Write for 144-page handbook — Free. B.I.E.T. (Dept. 337H), 29 Wrights Lane, London, W.8. W 187

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BRITISH AIRWAYS STAFF HOUSING SOCIETY LIMITED. Applications are invited for 21-year leases of a few lock-up shops in a parade of 19 which will form the shopping centre of the new and part of the old community at Stanwell, near Staines, Middlesex. In addition the shopping centre will incorporate a Public House, Professional Suites, Church, Bank, etc. Lettings are required for the following trades not so far represented: Radio and Television, Baker and Confectioner, Wet and Fried Fish Shop, Boot and Shoe Sales and Repairs, Gentlemen's Outfitters, Dyers and Cleaners. For full particulars apply to: A. G. Edwards, Esq., F.R.I.C.S., A.M.Inst.C.E., Surveyor and Manager, British Airways Staff Housing Society Ltd., Airways House, Great West Road, Brentford, Middlesex. W 1188

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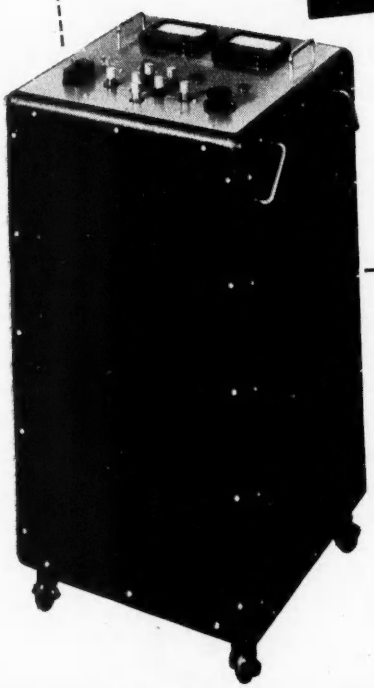

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Output 1—30 volts D.C. Current 0—7 amps

D.C. accuracy 25mV. Rectifier ripple less

than 0.05% peak (at full load).

Write for List of Servomex range of Electrical Control Instruments.

SERVOMEX CONTROLS LTD., CROWBOROUGH HILL, JARVIS BROOK, SUSSEX. TEL : CROWBOROUGH 1247.

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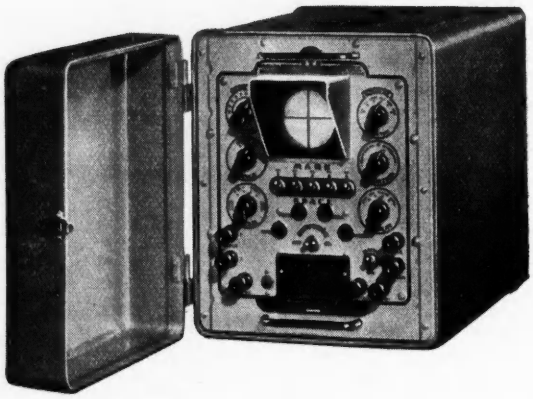
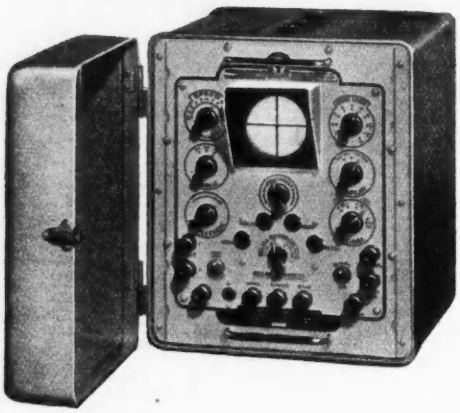
The T.D.M.S. 5 & 6 are portable sets designed to measure distortion at any point in a radio teleprinter or line telegraph circuit without interfering with normal transmission.
The equipment consists of two units each 12″ x 8″ x 7″ both mains driven and electronically controlled; either may be used independently for certain tests or both may be used in combination to cover a comprehensive range of testing operations.





T.D.M.S. 5

Sends an automatic test message or characters or reversals at any desired speed and/or percentage of distortion. The CRO has a circular time base for distortion measurements or relay adjustment.

T.D.M.S. 6

For distortion measurements on working circuits without interrupting service. Each element of a start-stop signal appears separately on the spiral time base display. Adjustable speeds from 20–160 bauds.

You are invited to apply for a copy of a descriptive leaflet which describes the equipment in detail

Automatic Telephone & Electric Co. Ltd.

Radio and Transmission Division, Strowger House,
Arundel Street, London, W.C.2. Telephone: TEMple Bar 9262. Cablegrams: Strowgerex London.

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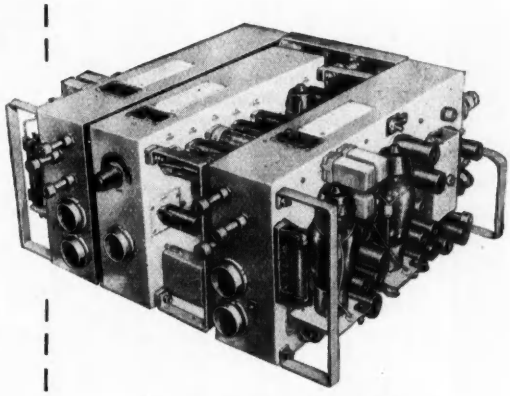
In the sphere of electronics, whatever you have to produce, whatever its state of development—if you want it produced quickly, in quantity, with commensurate quality; if you want it produced economically—it's a job for Plessey!

At the Electronics Division of Plessey, a thousand pairs of trained hands can, if need be, nurse a young idea—develop it—and bring it to full or limited production maturity with a thoroughness that would spell costly delay in any organisation less well equipped. The Division is presently engaged on contracts for for such renowned organisations as B.T.H., Decca, I.A.L., Kelvin Hughes, Marconi's Wireless Telegraph Company Ltd., and Laurence Scott & Electromotors Ltd. If your special interests lie in electronics, serve them well by writing for the Plessey publication which sets out the Division's specialised services.



Part of a particularly compact radar installation made for Marconi's Wireless Telegraph Company Ltd.

. . . you should see Plessey

ELECTRONICS DIVISION · TELEPHONE VALENTINE 8855

THE PLESSEY COMPANY LIMITED · ILFORD · ESSEX

PE 2a

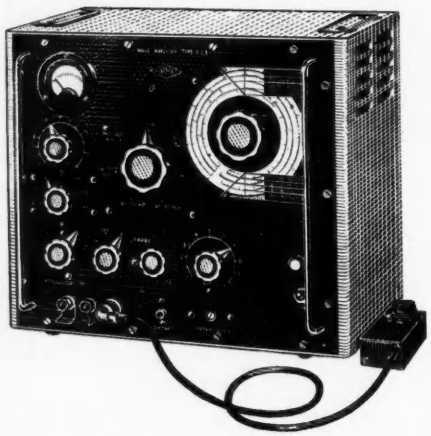
AIRMEC

H.F. WAVE ANALYSER TYPE 853

(Selective Measuring Set 30 kc/s—30 Mc/s)

CAN BE EMPLOYED

(a) To measure insertion gain and loss
(b) To measure field strength and interference
(c) For harmonic analysis
(d) As a selective Voltmeter
(e) As a Bridge Detector
(f) As a Heterodyne Wavemeter



THIS instrument is a selective measuring set of great versatility operating over the frequency range 30 kc/s–30 Mc/s. It consists essentially of a stable high-gain selective amplifier, operating on the heterodyne principle and incorporating H.F. and L.F. attenuators. The output, in the form of an audio frequency, is applied to a meter circuit and to headphones.

Special features are the high sensitivity (1 microvolt up to 20 Mc/s), wide attenuator range (120 db), high accuracy of attenuation (±0.1 db overall on L.F. attenuator), high selectivity, low noise level and continuous coverage over the whole frequency range.

SPECIFICATION

Frequency range : 30 kc/s—30 Mc/s in 7 ranges.

Amplitude range : 30 kc/s—20 Mc/s : 1 μV to 120 db above 1 μV. 20 Mc/s—30 Mc/s : 4 μV to 120 db above 4 μV.

Selectivity : 3 kc/s bandwidth.

Harmonic measurement : 2nd harmonics 70 db down and 3rd harmonics 90 db down can be measured.

Attenuators : R.F. Attenuator 0—60 db in 20 db steps, L.F. Attenuator 0—60 db in 10db steps and a 10 db variable attenuator

Input Impedance : 75 ohms. A high input impedance probe unit is also provided.

Full details of this or any other Airmec products will be forwarded gladly upon request.

AIRMEC LIMITED

HIGH WYCOMBE BUCKINGHAMSHIRE ENGLAND

Cables : Airmec, High Wycombe
Tel : High Wycombe 2060

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SERIES 500

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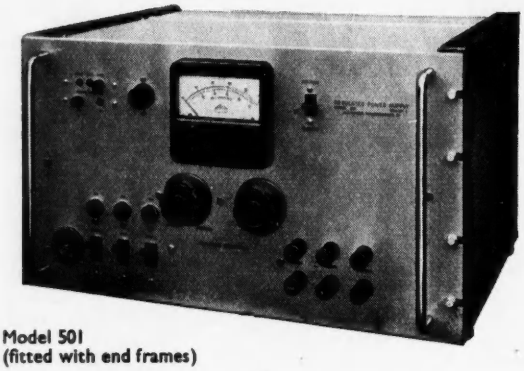
Now in large scale production and available for prompt delivery.



Model 501
(fitted with end frames)

ABRIDGED DATA

(Further information on request)

	Data	Model 501	Model 502	Model 503	Model 504	Model 505
Main +VE Stabilizer	Output	200-500V 250mA	200-500V 250mA	0-500V 250mA	0-500V 250mA	0-500V 150mA
	Number of Ranges	2	2	4	4	1
	Voltage Stabilization	±0.02%	±0.002%	±0.1%	±0.002%	±0.1%
	Effective Output Resistance (max.)	0.2 Ω	0.02 Ω	0.5 Ω	0.02 Ω	0.5 Ω
	Output Ripple (rms. max.)	2mV	1mV	3mV	1mV	3mV
−VE Supply Stabilizer	Outputs	—	—	250V 25mA 0—250V 1mA	250V 25mA 0—250V 1mA	250V 25mA 0—250V 1mA
	Voltage Stabilization	—	—	±0.05%	±0.002%	±0.05%
	Output Resistance (max.)	—	—	1 Ω	0.01 Ω	1 Ω
	Output Ripple (rms. max.)	—	—	2mV	1mV	2mV
Unstabilized +VE H.T. Supply 250mA max.		470V 630V	470V 630V	320V 470V 630V	320V 470V 630V	630V
Unstabilized A.C. Supply		6.3V 10A	6.3V 10A	6.3V 10A	6.3V 10A	6.3V 10A
Price		£70	£91	£81	£99	£75

STANDARD UNITS. All models are supplied as standard for mounting in 19 in. racks and are fitted with fully protective covers.

EXTRAS. To convert from rack mounting to bench use the following extras are available :—

Polished hard-wood reinforced end frames ... ... £1 15 0 per pair

Steel instrument case of new design ... ... £4 10 0 each

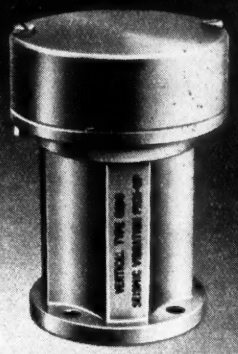
PRICES. Prices are quoted net ex works and are subject to variation without notice.

ALL-POWER TRANSFORMERS LTD. . CHERTSEY ROAD, BYFLEET, SURREY.
Tel. : BYFLEET 3224/5

MINIRACK

VIBRATION PICK-UPS
for
MINIRACK OSCILLOGRAPHS

G225B SEISMIC
VIBRATION PICK-UP
(Inductance Type)



G266 SEISMIC
VIBRATION PICK-UP
(Electro Magnetic Generator
Type)

G209 SEISMIC
VIBRATION PICK-UP
(Inductance Type)

G211 PROXIMITY VIBRATION
PICK-UP
(Inductance Type)

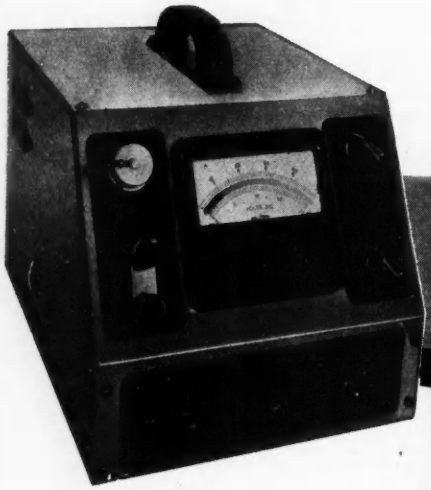
G226 ACCELEROMETER
(Capacitance Type)

Please write for new catalogues

SOUTHERN INSTRUMENTS LTD

CAMBERLEY SURREY

Telephone: Camberley 2230 (3 lines) Telegraphic Address: Minrak, Camberley, England



Multi Range VOLTMETER

current drain less than 10^{-11} amps

Based on a well-known A.E.R.E. design, the HYZEE Electrometer Voltmeter has an input resistance of the order of 10^{13} ohms. The instrument can thus be connected to a circuit without disturbing the existing conditions.

Specification

Ranges :	0-10, 20, 50, 100, 200, 500 volts—either polarity.
Accuracy :	±1.25% of scale reading.
Zero Drift :	Less than 1% of full scale deflection per hour after five minutes warming on 10 volt range or less on higher ranges.
Mains :	±10% deviation from the nominal mains voltage will affect the zero and calibration by less than 0.2v. on all ranges.

Power Supply: 200-250 volts 50 c/s.

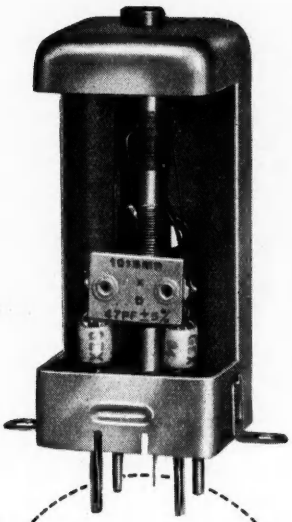
Typical applications are :—

- Volt-drop across high resistors.
- Valve grid currents.
- High value resistors.
- Insulator surface or volume leakage.
- Electrostatic field measurement.

BALDWIN *scientific instruments*

BALDWIN INSTRUMENT COMPANY LTD. · DARTFORD · KENT Telephone : 2948

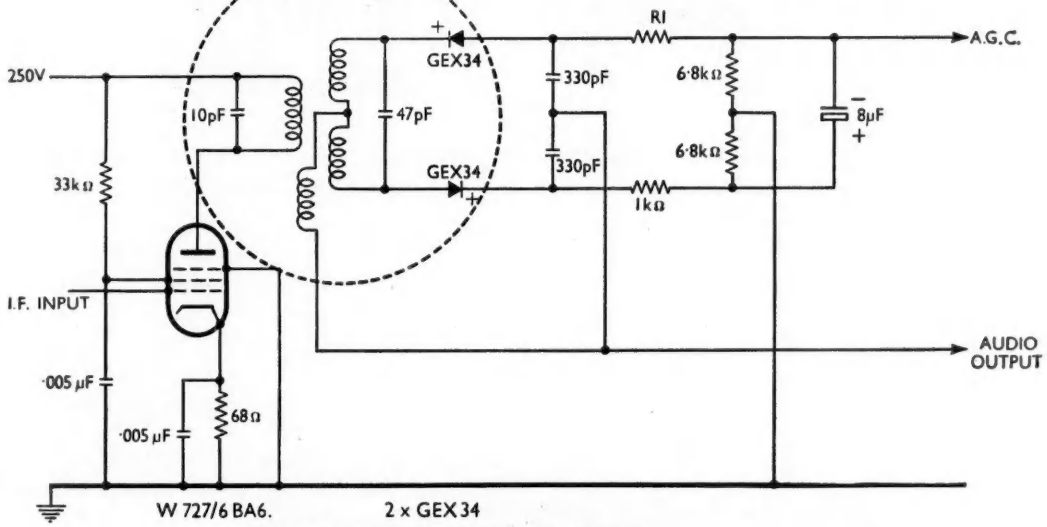
G.E.C. GERMANIUM DIODES



GEX 34 in the Ratio Detector

The Ratio Detector has been generally accepted as the most practical form of detector for receivers designed for the new High Quality F. M. Service to be inaugurated next year, since it obviates the need for a separate limiter stage.

The illustration shows the application of two GEX 34 in a typical ratio detector where full advantage has been taken of its small size by enclosing them in the I.F. transformer can. This construction reduces the risk of instability and eliminates the possibility of harmonic feed back via the heater leads.



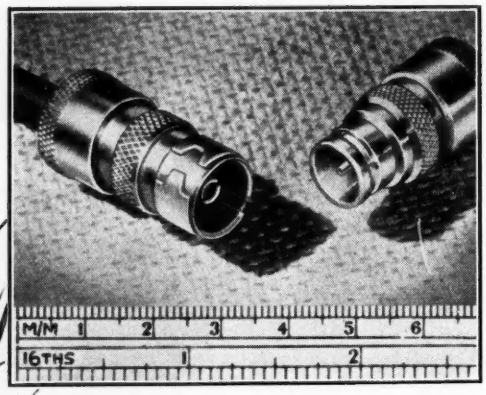
ADJUST RI FOR MINIMUM A.M. OUTPUT

Transformer Design. Although the circuit shown above is conventional, an I.F. transformer designed for use with thermionic diodes is not necessarily the most suitable for germanium diodes. A suitable design of transformer has been evolved at The G.E.C. Research Laboratories, details of which are available on request.

Write to The Osram Valve and Electronics Department,

THE GENERAL ELECTRIC CO. LTD., MAGNET HOUSE, KINGSWAY, W.C.2.

Good connections in less time

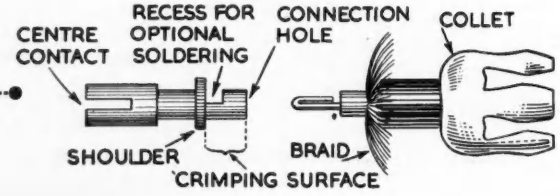


* *Special feature of B-L Co-axial Socket enables crimping over feeder*

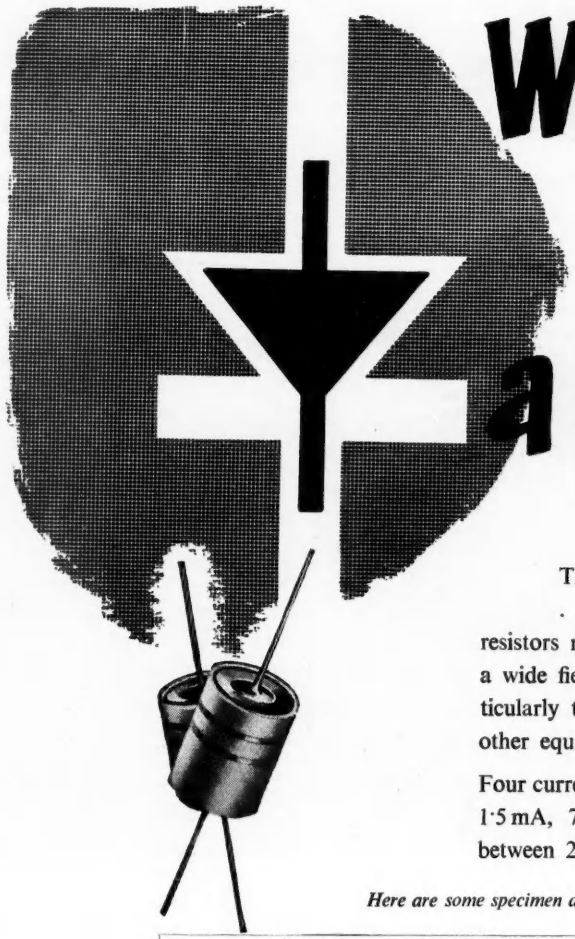
A fault commonly experienced in the laboratory, workshop and in domestic television installation is the tendency to attach co-axial plugs and sockets in a careless manner. Often the feeder is merely pushed through the co-axial pin without soldering, leaving a loose, dry joint.

To facilitate a good connection in the minimum time we have incorporated a feature in our Co-axial Free Socket L.734/J to enable plug and socket to be crimped over the feeder.

In addition to the crimping surface, a recess for soldering is provided. However, crimping is usually preferred and in this manner a good connection can be made in seconds by a grip of the pliers, thus eliminating a possible source of future trouble.



BELLING & LEE LTD
GREAT CAMBRIDGE ROAD, ENFIELD, MIDDX., ENGLAND



When is this NOT a rectifier?

The answer, of course, is when it's a UNISTOR . . . from that useful range of asymmetric resistors made by *Standard*. **SenTerCel Unistors** have a wide field of application in electronic circuits, particularly those associated with digital computors and other equipments of a similar nature.

Four current ratings are at present available . . 0·25 mA, 1·5 mA, 7 mA and 10 mA at various D.C. voltages between 20 and 100V.

Here are some specimen data.

Unistor Code	D.C. Current Rating in Max. Ambient Temp. 55°C.	71°C.	Maximum Continuous Inverse D.C. Voltage	Maximum Instantaneous Inverse D.C. Voltage	Capacitance at Approx. Zero Volts
	mA	mA	Volts	Volts	pF
Q1/1	0·25	0·25	20	56	20
Q3/1	1·5	1·5	20	56	65
Q6/1	7	3	20	56	500
Q8/1	10	4	20	56	1,000

SenTerCel UNISTORS

(asymmetric resistors)

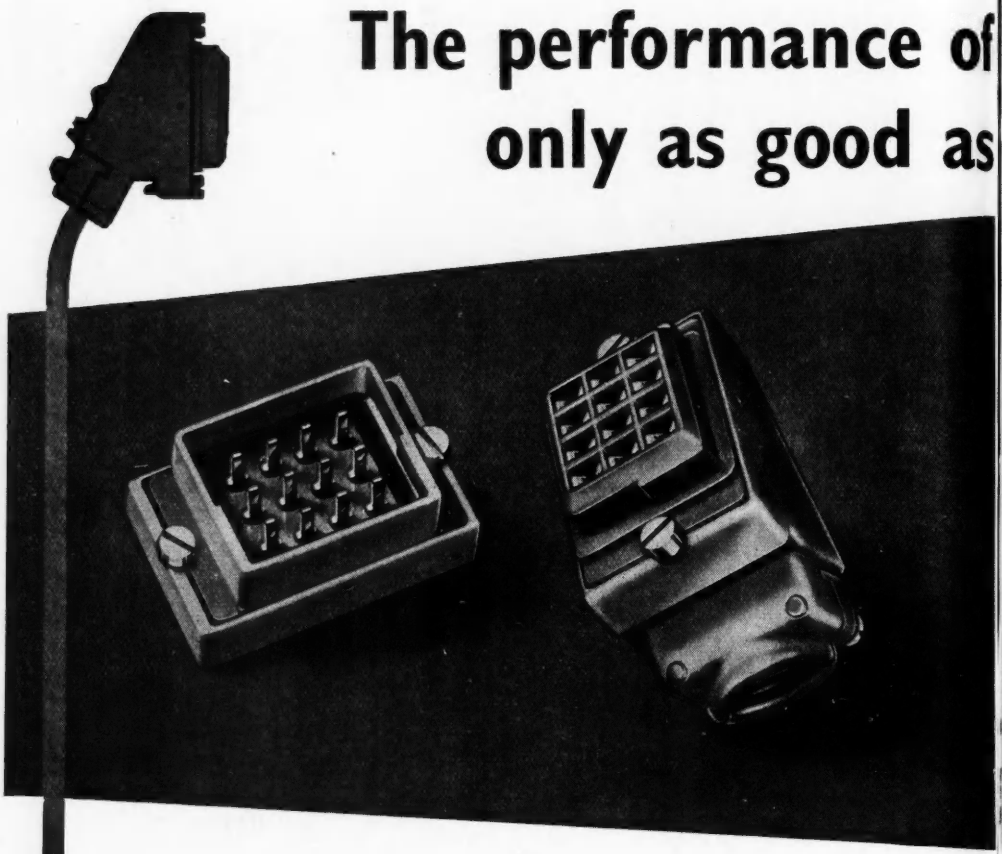
Standard Telephones and Cables Limited

Registered Office: Connaught House, Aldwych, W.C.2

RECTIFIER DIVISION: Warwick Road, Boreham Wood, Hertfordshire

Telephone: Elstree 2401 **Telegrams: Sentercel, Borehamwood**

The performance of any only as good as its



Multiway Plugs and Sockets for quick action and positive contact

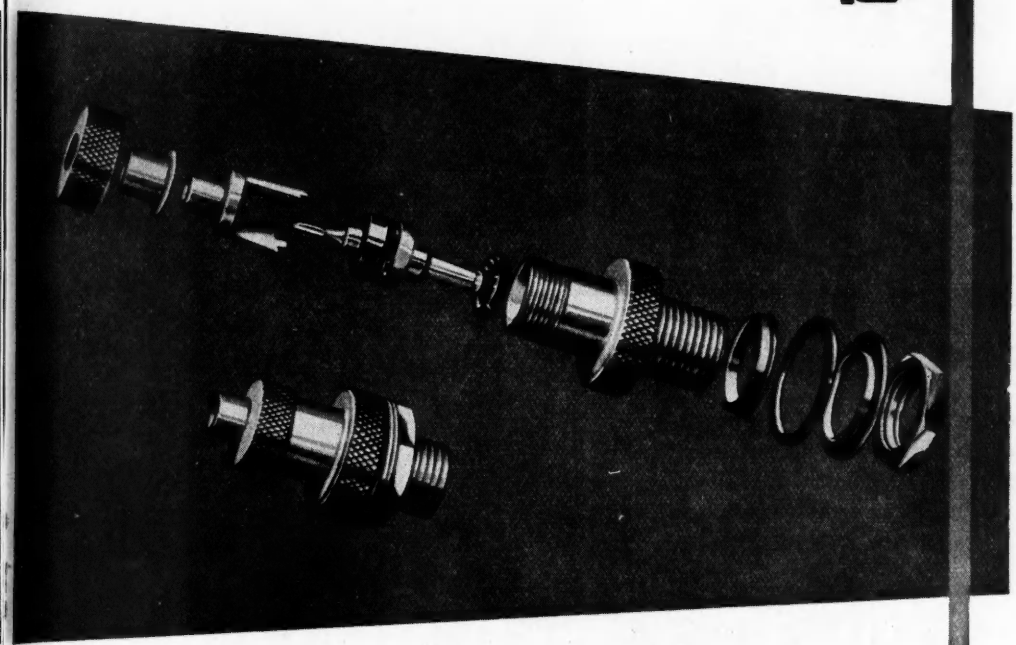
These reliable Plugs and Sockets, proved in service, provide a quick positive connection for up to 28 terminations. They need lower insertion pressure per contact than any comparable product, and when fully mated a dust and damp proof seal is provided between Plug and Socket. Considerable latitude in matching can be allowed when they are used in rack mounting applications.

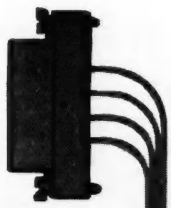
These components are in regular use by :— The English Electric Co. Ltd., Messrs. Marconi's Wireless Telegraph Co.Ltd. and Messrs.Standard Telephones&Cables Ltd.

4 WAY 8 WAY 12 WAY 20 WAY 28 WAY

PLEASE WRITE FOR FURTHER DETAILS TO

# of any equipment is as its terminals





These versatile Miniature connectors provide perfect coupling between co-axial cables and instruments, and are extensively used in Television, Radar, and Communications equipment. They are 100% pressure and flash tested before despatch. The full range consists of a variety of Cable and Panel Mounting units of either plug or socket type, and a recent addition is an elbow connector for applications where it is desired to keep the face of the panel clear. Suitable for use with co-axial cable Uniradio 32 and 43.

Miniature hermetically sealed Co-axial Plugs and Sockets to RCS.322

A.I.D & A.R.B — APPROVED

POWER CONTROLS
LIMITED

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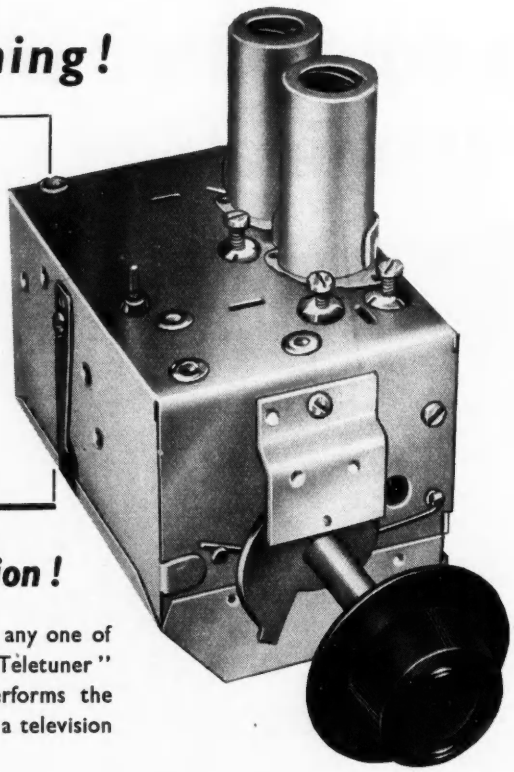
Multi-channel tuning!

Cyldon

"TELETUNER"

(TRADE MARK)

Type TV.12



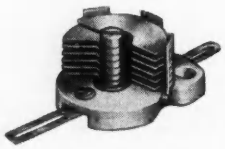
Instant, single-knob selection!

Select a frequency in the 50-220 Mc/s range—select any one of twelve in fact—and this new Cyldon Multi-channel "Teletuner" will handle it. This compact two valve unit performs the functions of R.F. amplifier and frequency changer in a television receiver. ***Write for Folder TV 1953.***

FOUR NEW TRIMMERS

by the Makers of "Cyldon" Trimmers and Variable Capacitors

No. 26. Mica Compression Trimmer.



No. 28. Air Spaced Trimmer

No. 29. Glass Trimmer.

No. 30. Ceramic Trimmer

Full details and specifications available on application

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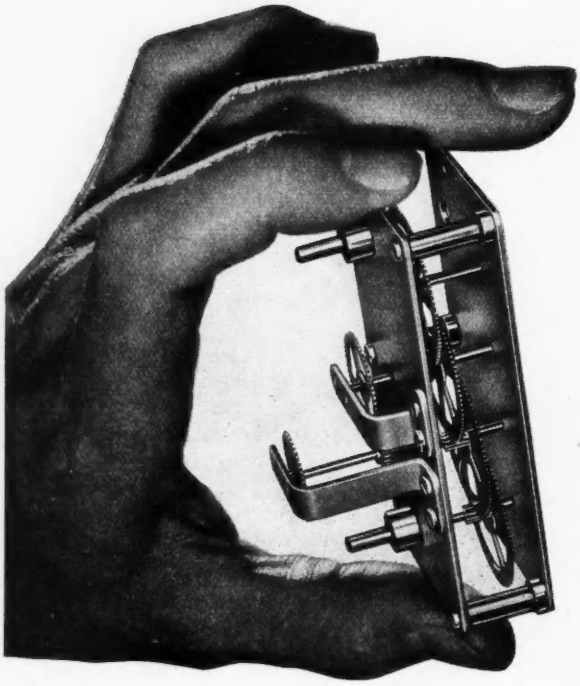
LG 2

FINE **WORK**



-in DURALUMIN

REGD. TRADE MARK

by **FERRANTI**

This tiny but important meter train by Ferranti Limited, is not only an example of the fine precision work carried out by that famous organisation but also demonstrates the way in which "Duralumin" can assist in developments in the electrical field.

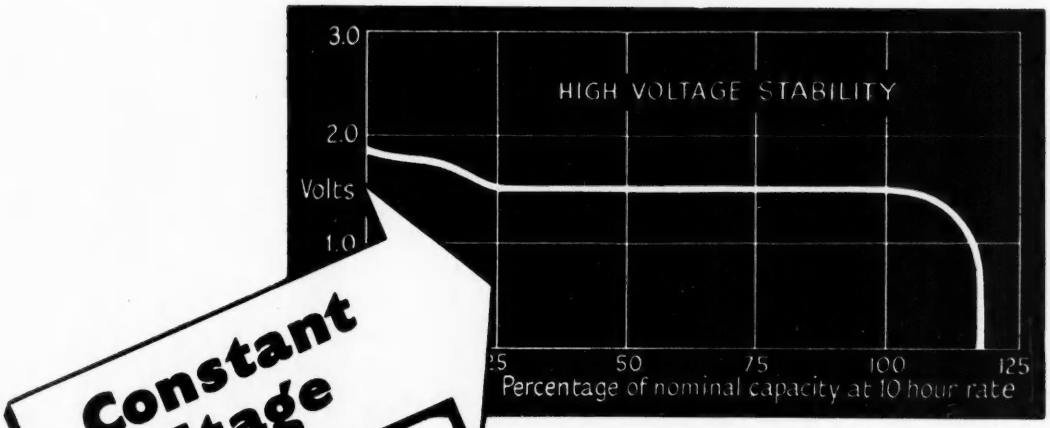
The construction is largely in "Duralumin" manufactured to very fine tolerances and its use means that less power is required to drive the train, the accuracy of the meter thereby being increased.

"Duralumin" is one of a comprehensive range of light alloys developed by James Booth & Company Limited, and these modern materials are being increasingly used with great advantages in electrical engineering and electronics. Our Development Department will always be pleased to offer advice entirely without obligation.

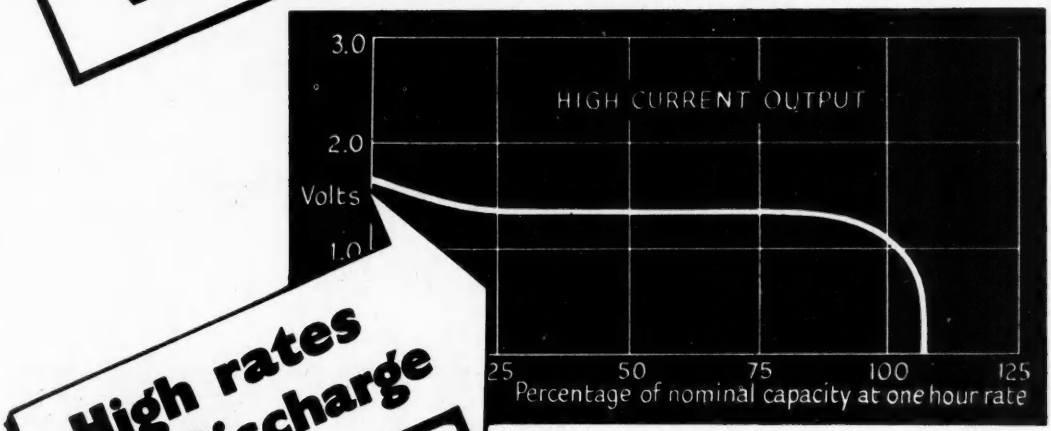
JAMES BOOTH & CO. LTD · ARGYLE STREET WORKS · BIRMINGHAM · 7

BOOTH BIRMINGHAM

Outstanding Characteristics



Constant Voltage



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The Venner Lightweight silver-zinc Accumulator is now in world-wide use by Government departments and industrial undertakings where unnecessary weight and size is a serious disadvantage.

It provides an almost perfect source of constant voltage, especially when the discharge is low, due to the storage capacity of silver-zinc cells being greatly superior to that of lead-acid. In addition, the extreme high rates of discharge with little drop in effective capacity is remarkable for so small a rechargeable battery and is equivalent to, and exceeds in many cases, the ordinary cumbersome and heavyweight types.

The Venner Lightweight Accumulator is exceptionally valuable for aircraft and marine applications, miners' lamps, photographic flash outfits and all battery operated electronic devices.

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Wherever an efficient combination of mechanical strength and sound insulating properties is required, 'Pirtoid' provides the modern answer.
Superior under severe operating conditions, resistant to shock loading, easily punched to yield clean, sound blanks, amenable to effective drilling without delamination, 'Pirtoid'—for Terminal Supports and Bases, Brush Holders, Bobbins and Coil Formers, Panels, Insulating Bushes and Handles—is the material of the moment.

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PIRTOID IS A SYNTHETIC RESIN BONDED LAMINATED FABRIC OR PAPER BASED SHEET TO APPROVED A.I.D. SPECIFICATION AND CAN BE MACHINED, FORMED OR MOULDED TO ANY SHAPE

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High Performance
VOLTAGE STABILISERS and REFERENCE TUBES

Close tolerance burning voltages
Wide range of operating temperature
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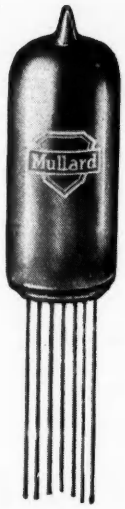
Freedom from output voltage "jumps"
Long operating life

NOW

ALSO AVAILABLE IN
SPECIAL QUALITY RANGE



The high performance of Mullard stabilisers has been improved even further by the introduction of *Special Quality* types, which will operate satisfactorily under rigorous conditions of shock and vibration. These special versions of normal production types combine extra-rugged construction with what has proved to be an inherently reliable principle of design, and they will be available in addition to the normal range.
Samples selected from every production batch of *Special Quality* tubes are tested against Services' specifications to withstand impacts of 500g and vibration of 6g at 175 c/s.
All three of the *Special Quality* tubes can be supplied with either pin or flying lead bases. Your enquiries for further details of these and other stabilisers in the Mullard range are welcomed at the address below.

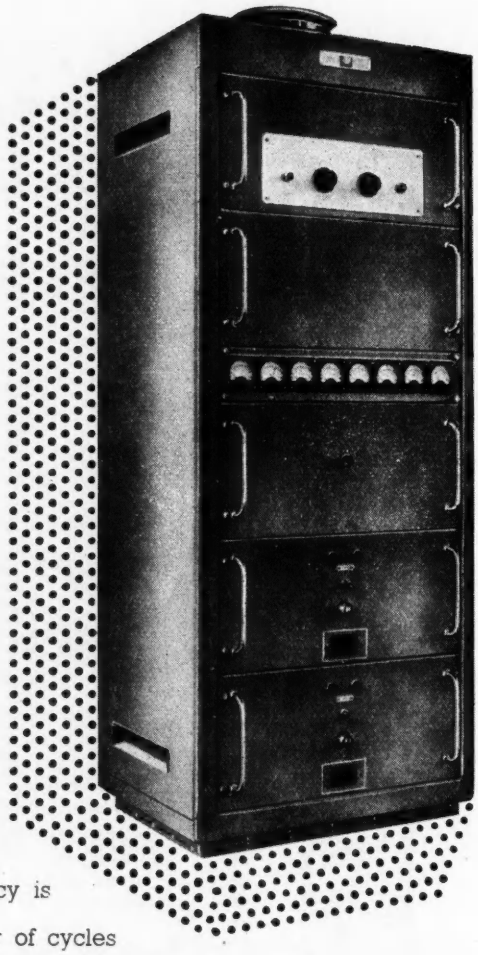
Special Quality Type No.		Electrical Equivalent		Burning Voltage (V)	Current Range (mA)	Maximum Ignition Voltage (V)
Pin Base	Flying lead Base	Mullard	British Services			
M8098	M8142	85A2	CV449	85	1 to 10	115
M8206	M8207	90C1	—	90	1 to 40	115
M8163	M8208	150B2	CV2228	150	5 to 15	180

Mullard
SPECIAL QUALITY VALVES

MULLARD LTD., COMMUNICATIONS & INDUSTRIAL VALVE DEPT., CENTURY HOUSE, SHAFTESBURY AVENUE, LONDON, W.C.2

MVT 170

AUTOMATIC FREQUENCY MONITOR (20 Mc/s)



Designed for the measurement of any frequency in the range 10 c/s to 20 Mc/s with a basic accuracy of ± 1 part in 10^6 ± 0.1, 1.0, or 10 c/s. Higher accuracies available if required. The unknown frequency is determined by counting the number of cycles that pass through a 'gate' open for a selectable time interval of 0.1, 1.0, or 10 seconds. The result is presented on eight panel mounted meters each scaled 0 to 9 and is in decimal notation. Full information available on request.

CINEMA-TELEVISION LIMITED

A Company within the J. Arthur Rank Organisation

WORSLEY BRIDGE ROAD · LONDON · SE26

Telephone HITher Green 4600

SALES AND SERVICING AGENTS

F. C. Robinson & Partners Ltd., 287 Deansgate, Manchester, 3

Hawnt & Co., Ltd., 89 Moor St. Birmingham, 4

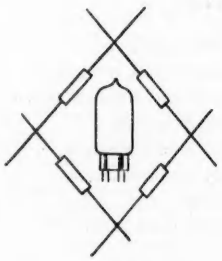
Atkins, Robertson & Whiteford Ltd. 100 Torrisdale Street, Glasgow, S.2

On the face of it

. . . it is evident that **BRIMAR** high-grade cathode-ray tubes meet the most exacting specifications of television and electronic equipment manufacturers.

And detailed examination of the company's resources and experience in this field reveal that BRIMAR introduced :—

- **the first mass produced aluminised cathode-ray tube;**
- **the first flat faced tube ;**
- **the first 14″ rectangular tube ;**
- **the first 17″ rectangular tube ;**
- **the first 21″ rectangular tube ;**
- **the first electro-static tube.**



Research and development to anticipate and meet the changing demands of the radio and electronic industries are integrated with modern manufacturing techniques in the production of BRIMAR cathode-ray tubes.

Consult BRIMAR *—the people who know—for your future equipment requirements.*

Standard Telephones and Cables Limited

FOOTSCRAY · SIDCUP · KENT. *Telephone:* **FOOtscray 3333**

. . . . IN THE PROTECTION OF EFFICIENCY

We can safely claim there are no chinks in our armour when it is a matter of manufacturing winding wire. Better equipped than ever before, from our new factory at Kirkby we are supplying increasing numbers of electrical component manufacturers throughout the world. Our range of products, too, has increased, and includes paper covered, cotton and glass covered strips. Your enquiries will be welcomed. Samples gladly supplied on request.

The largest manufacturers of fine enamelled wire in the world.

CONNOLLYS *Winding Wires*

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Kirkby Industrial Estate, Liverpool

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EUSton 6122

MIDLANDS :
15/17, Spiceal Street, Birmingham
MIDland 2268

This low frequency oscillator costs only £75

(Bench stands 1 gn. extra)

This reasonably-priced low frequency oscillator is extensively used in the aircraft industry and elsewhere as a convenient source of signals down to 1.15 c.p.s. for the testing and calibration of vibration recorders, servo systems etc. It is also widely used in medical research and clinical work for the calibration of biological amplifiers and recorders, and low frequency wave analysers.

Brief Specification:

TYPE	FREQUENCY RANGE	OUTPUT	INPUT	CONSTRUCTION
Resistance capacity, with automatic amplitude control effective over the whole frequency range.	1.15 c.p.s. to 5,500 c.p.s.	Sine wave 50 volts peak to peak push-pull, with built-in attenuator.	200-250 volts, 40-60 c.p.s.	Standard 19" rack mounting, but also suitable for bench use. Bench stands available.

NOTES. An incremental switch is fitted. Provision is made for mixing other signals with the output.

Immediate delivery from

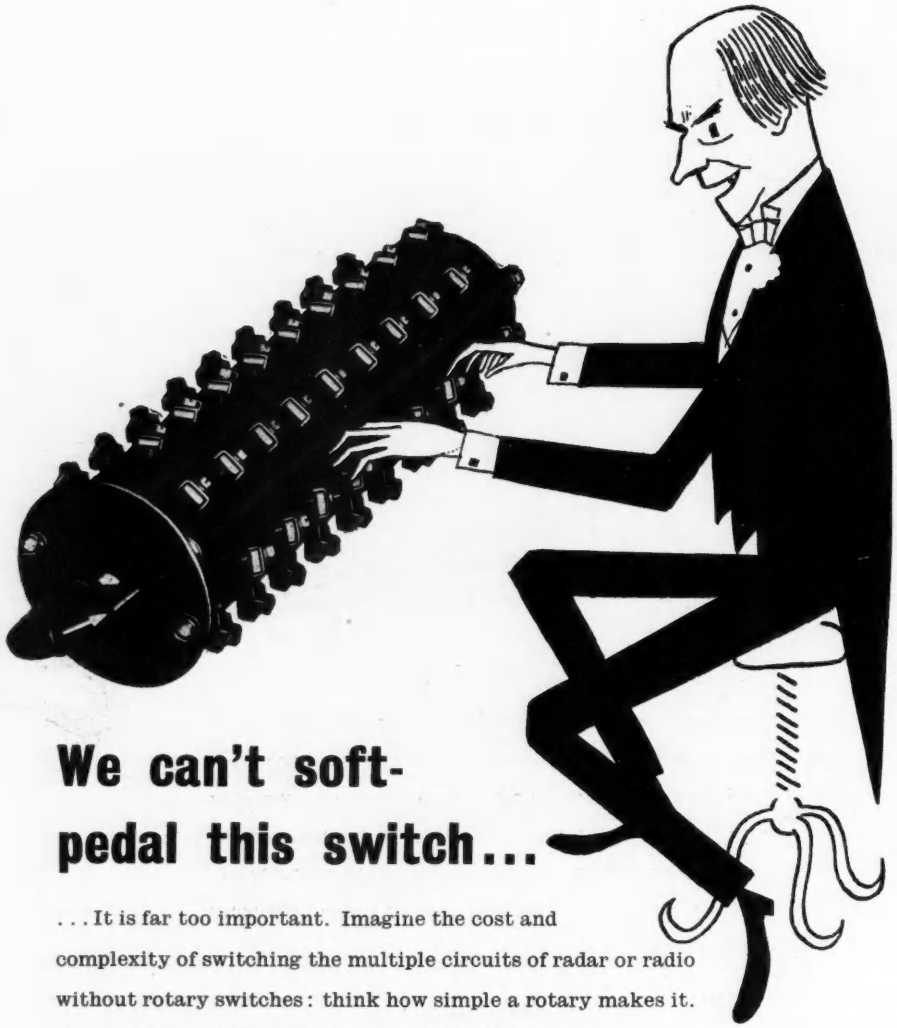
EDISWAN

RADIO DIVISION · THE EDISON SWAN ELECTRIC COMPANY LIMITED

Member of the A.E.I. Group of Companies

155 Charing Cross Road, London, W.C.2. *Telephone:* Gerrard 8660. *Telegrams:* Ediswan, Wescent, London

SP 130



We can't soft-pedal this switch...

. . . It is far too important. Imagine the cost and complexity of switching the multiple circuits of radar or radio without rotary switches: think how simple a rotary makes it. Go on to ask the obvious question: Why not the same simplification of industrial power switching? Why not indeed! Austinlite Rotaries are designed for that very purpose. They switch more compactly, more cheaply, more simply than conventional switchgear . . . and every switch is built for its job. Tell us what the circuits are: we will supply an Austinlite — no matter how special — to switch them. The switches are described in a technical brochure 'Simplified Switching' — copies are available on request.

Rotary switching is 'Simplified Switching'

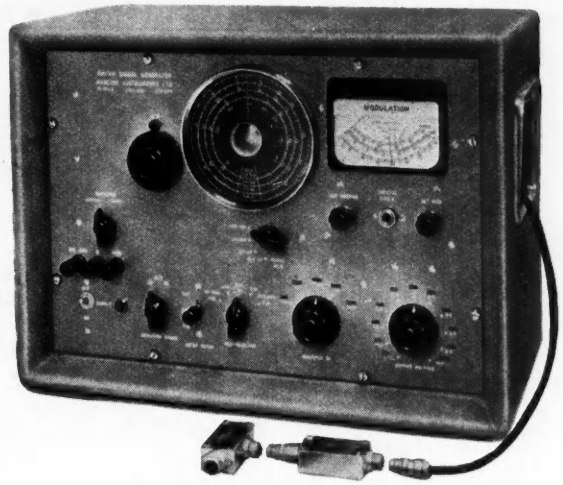
ask *Austinlite* about it

AUSTINLITE LIMITED, LIGHTHOUSE WORKS, SMETHWICK 40, BIRMINGHAM

(A subsidiary of Stone-Chance Ltd., the makers of Sumo Pumps and Stone-Chance Lighthouses)

Marconi Signal Generator Type TF 995A/1

For both r.f. and i.f. testing with c.w., f.m., a.m., or simultaneous f.m. and a.m.



The MARCONI Signal Generator Type TF 995A/1 is a compact, transportable, a.c. operated instrument. It covers from 2 to 216 Mc/s in five bands and there are facilities for crystal standardization from 13.5 Mc/s upwards; its open-circuit output level is variable, in 1-dB steps, from a minimum of 0.1 μV to a maximum of 100 mV at 52Ω, and 200 mV at 75Ω. The output may be continuous wave, frequency modulated, amplitude modulated, or simultaneously both frequency and amplitude modulated. The modulation, obtained either from an internal 1000-c/s oscillator or from an external source, is variable to maximum frequency deviations ranging from 25 to 600 kc/s for f.m., and to depths up to 50% for a.m.

MARCONI INSTRUMENTS

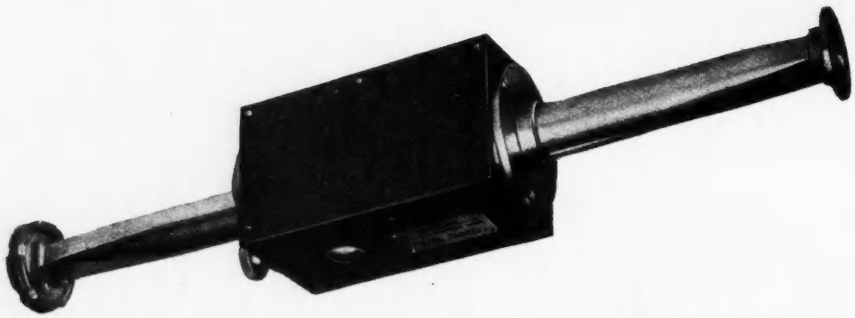
SIGNAL GENERATORS · BRIDGES · VALVE VOLTMETERS · Q METERS · WAVEMETERS
FREQUENCY STANDARDS · WAVE ANALYSERS · BEAT FREQUENCY OSCILLATORS

MARCONI INSTRUMENTS LTD · ST. ALBANS · HERTS · Telephone: ST. ALBANS 6160/9
Midland Office: 19 The Parade, Leamington Spa **Northern Office:** 30 Albion Street, Kingston-upon-Hull
Export Office: Marconi House, Strand, London, W.C.2.

TC56

IMPORTANT ADVANCE IN THE TECHNIQUE OF

Microwave Measurement



LAW OF ATTENUATION CALCULABLE • INDEPENDENT OF FREQUENCY AND OF THE STABILITY OF THE ABSORBING ELEMENTS • NO PHASE SHIFT WITH CHANGE OF ATTENUATION

The law of the instrument—

Attenuation (decibels) = 20 log. $\sec^2\theta$ (where θ is the reading of the geometric scale of the instrument)

enables it to be put to a great number of applications. Typical is its use with a Standing Wave Indicator.

If constant crystal current is maintained at the indicator while moving from the minimum to the maximum of the standing wave, by introducing attenuation (from zero) into the Attenuator, it can be shown that Cos θ (or Sec θ depending upon which system you use) is the voltage Standing Wave Ratio, at any frequency.

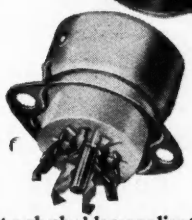
Computed tables both for V.S.W.R. and Voltage Reflection Coefficient are available with the instrument.

Recent experience has shown that accuracy is considerably better than the advertised figures of 0.1 db. to 20 db. ; 0.2 db. to 30 db. ; and 0.3 db. to 40 db. Full details on request.

ELLIOTT

ROTARY ATTENUATORS

ELLIOTT BROTHERS (LONDON) LTD. CENTURY WORKS, LONDON, S.E. 13 (TIDEWAY 3232)



Why Ediswan Clix P.T.F.E. Valveholders are widely used in B.B.C. Television equipment

Large quantities of Ediswan Clix P.T.F.E. Valveholders are used in B.B.C. Television equipment. Only the combination of the finest insulation—P.T.F.E., the most efficient contact material—Berylium copper—and Ediswan Clix design and manufacture can match the requirements of efficiency and reliability in this and all other stringent valveholder applications.

Ediswan Clix P.T.F.E. Valveholders are fully type approved for Services Grade 1, Class 1 conditions. Full details of these valveholders and other components in the Ediswan range are given in catalogue CR. 1681. Manufacturers and Development Groups may have a copy on request.

EDISWAN

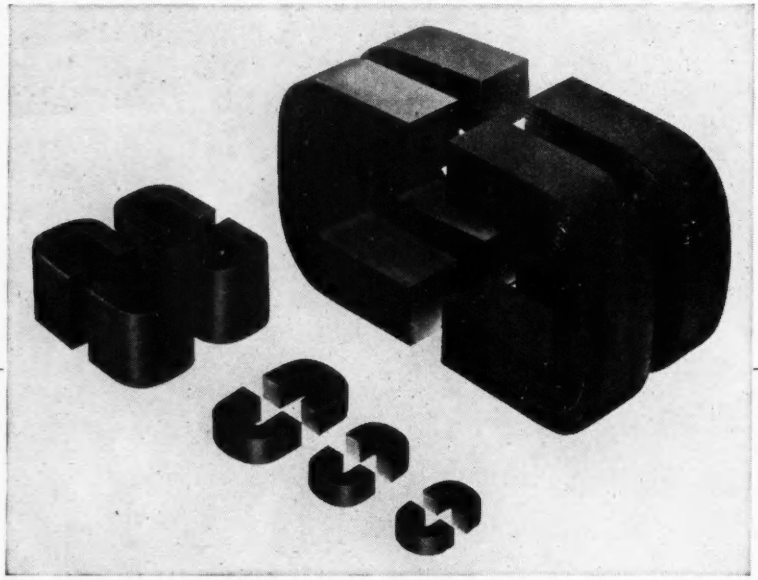
CLIX

RADIO, TELEVISION & ELECTRONIC COMPONENTS

THE EDISON SWAN ELECTRIC COMPANY LIMITED, *Member of the A.E.I. Group of Companies*
155 Charing Cross Road, London, W.C.2 and Branches. *Telephone: Gerrard 8660. Telegrams: Ediswan, Westcent, London*
CR3 Radio Components Sales Office: 21 Bruton Street, London, W.1. *Telephone: Mayfair 5543*

'C' type Cores

for small transformers and chokes



- Reduction in size and weight up to 30%
- High efficiency
- Low loss — low leakage flux — low magnetising v.a.
- Stability in temperatures up to 200°C.
- Ease of assembly and storage
- Suitable for open type, oil-filled or "cast-in-resin" type transformers.

Full interservice range of cores and accessories available on short delivery. Special cores to order.

Details of these 'C' type Cores will be supplied on request to:
Transformer Sales and Contracts Department, East Lancashire Road, Liverpool, 10.

'ENGLISH ELECTRIC'

'C' type Cores

THE ENGLISH ELECTRIC COMPANY LIMITED, QUEENS HOUSE, KINGSWAY, LONDON, W.C.2

TL.11 F4 WORKS: STAFFORD · PRESTON · RUGBY · BRADFORD · LIVERPOOL · ACCRINGTON

An outstanding general purpose communication receiver

Justly acclaimed as Britain's finest post-war communication receiver the BRT 400 D is in widespread use by Military, Post and Telegraph and Broadcasting authorities throughout the world.

Combining first-class performance with a wide range of facilities, the BRT 400 D is equally suitable for both narrow-band telegraphy and wide-band telephony reception—with a very high standard of reliability.

It is available in either cabinet or rack mounting form, with a 500 kc/s crystal calibration unit as an optional extra. Normal operation is from an A.C. mains supply: an auxiliary power unit is available for 12 volt battery operation.

G.E.C.

BRT 400D

SHORT SPECIFICATION

BAND COVERAGE

0.150—0.385 Mc/s } in 6 bands
0.510—30.0 Mc/s }

SENSITIVITY

Better than 1.0 μV for 1.5 watts output, over the whole band.

SIGNAL/NOISE RATIO

Standard input for 20 db:—

1.3—30.0 Mc/s	< 7.0 μV
0.150—1.3 Mc/s	< 10.0 μV

SELECTIVITY

Six switched bandwidths:—

0.5 kc/s	1.0 kc/s	2.0 kc/s
5.5 kc/s	9.0 kc/s	13.0 kc/s

OVERALL FIDELITY

Less than 2 db down at 50 c/s
Less than 6 db down at 5,500 c/s

A.G.C. CHARACTERISTICS

Output constant within 3 db for 100 db change in signal input.

OUTPUT CIRCUITS

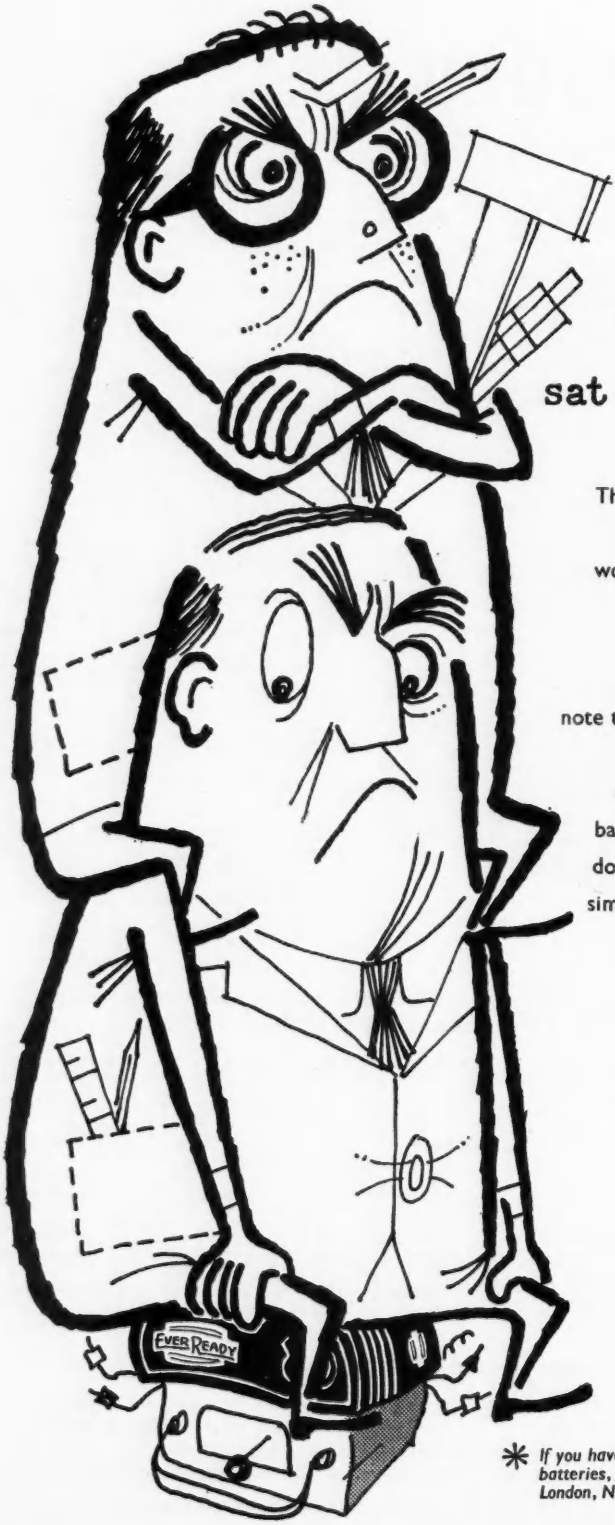
At 2.5 or 15 ohms	2.5 watts
At 120 ohms	0.05 watts
At 600 ohms	0.2 watts

POWER SUPPLY

95—130 and 195—250 volts, 40/80 c/s. Also from 12 volt battery, using BRT 401 auxiliary power unit.

For the full specification please send for a copy of publication BC2084.

THE GENERAL ELECTRIC CO. LTD., MAGNET HOUSE, KINGSWAY, LONDON, W.C.2



All the designers sat on the problem ..

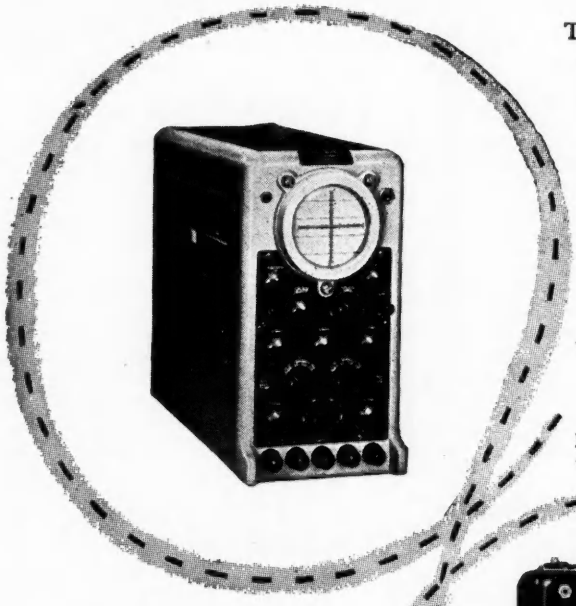
The design department had dreamed up a super portable but the battery just wouldn't go in. Unless specially designed batteries were ordered, the project would have to be quashed. Designers of battery radio sets should note this dilemma. Time, effort (and money) are wasted if you prepare a design and then find you haven't left room for the battery. Of course, Ever Ready can—and do—supply special units, but it's so much simpler to call us in early so that your set is designed, if possible, to take one of our many standard batteries.

EVER READY
REGD TRADE MARK

DRY BATTERIES FOR RADIOS

* *If you have a design problem involving dry batteries, get in touch with us at Hercules Place, Holloway, London, N.7 Telephone: ARChway 3030.*

COSSOR presents Model 1052 double beam oscillograph



Two similar amplifier channels with an approximate gain of 2000 and an upper frequency response of 5 megacycles (—6DB) are features of this new Cossor Double Beam general purpose oscillograph. The repetitive or triggered time base has a sweep duration from 200 milliseconds to 5 microseconds.

The instrument will operate from power supplies of any of the various frequencies and voltages encountered in the Armed Services or from standard civil supply mains.

Full-scale production of this instrument now enables us to announce a reduction in price.

and Model 1433 voltage calibrator

Primarily designed to be used with the Model 1052 oscillograph the Cosser Voltage Calibrator Model 1433 provides an accurate means of calibration of input voltages to the plates or amplifiers of any oscillograph. Calibrating voltages are read directly from a wide scale meter without any computation being necessary. Measurements can be made to an accuracy of ± 5% and the instrument can be used in any application where a source of accurately-known voltage is required.

C.I.56

COSSOR ELECTRONIC INSTRUMENTS

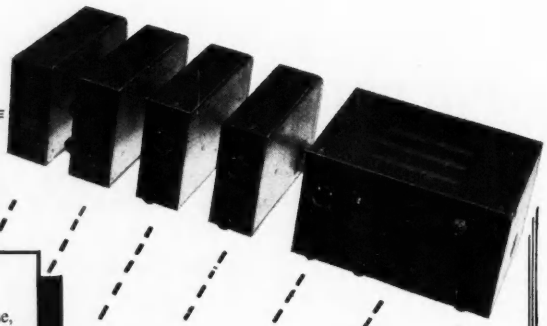
Watch out for the new ***Tele-check and crystal monitored marker generator*** *for bands* I *and* III

Write for illustrated leaflets about both of these instruments

A. C. COSSOR LTD., INSTRUMENT DIVISION, DEPT. 2, HIGHBURY GROVE, N.5

Telephone: CANonbury 1234 (33 lines). Telegrams: Cossor, Norphone, London. Cables: Cossor, London

ALWAYS USE COSSOR TUBES & VALVES



TYPE 101A ADD-ON COUNTER

Developed for industrial and research use, the Add-on range of counting equipment comprises a number of different units which are fitted together as required to provide versatile yet inexpensive devices for the solution of a variety of counting problems.

For normal counting purposes the Power Unit which incorporates the Input Decade is supplemented by as many decade "units" as the particular application requires. Auxiliary units enable the equipment to be used for batch counting, or for process timing.

The count is clearly displayed on ERICSSON long life cold cathode dekatron tubes.

The units are rigidly assembled in line, with electrical connection between units maintained through 12 pin plugs and sockets.

Available, either frame-mounted for standard rack (19"-48.3 cm) or with end plates for bench mounting.

ABRIDGED SPECIFICATION

Max counting speed 3,500 per sec.

Input Sensitivity 5V RMS (sine)
5V Peak (pulse)

Output pulse obtainable from each decade.

Internally derived 100 pulses/second for timing

Manual or electronic control of start, stop and reset.

Supplies available for input probe, etc.

Finish, green panel, hammer-green case.

ELECTRONIC T E L NUCLEONIC INSTRUMENTS

ERICSSON TELEPHONES LTD

HEAD OFFICE 22 LINCOLN'S INN FIELDS, LONDON, W.C.2 TELEPHONE HOL 6936

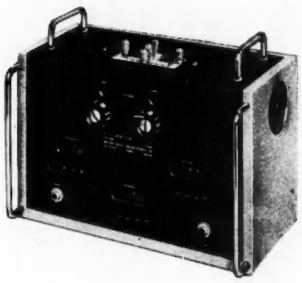
WORKS - BEESTON, NOTTINGHAM, ENGLAND

821

Three Versatile Instruments

FROM THE WAYNE KERR RANGE

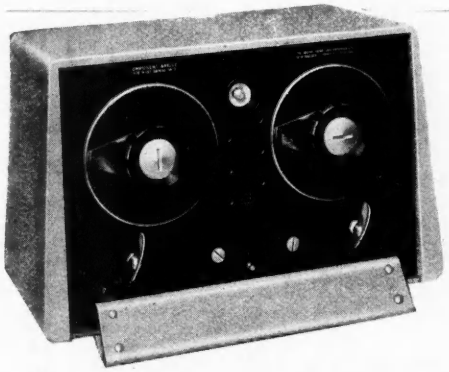
V.H.F. Impedance Bridge Type B.801



For balanced and unbalanced measurement from 1-100 Mc/s.

Susceptance: Equivalent to ±230 pF.	Conductance: 0-100 mmho.
Accuracy: ±2%, ±0·5 pF.	Accuracy: ±2%, ±0·1 mmho.

This is one of a range of bridges for use with external source and detector for the measurement of aerials, cables, feeders, and a variety of components and materials between 15 kc/s and 250 Mc/s. Bridge sources and detectors are available for use between 1-100 Mc/s and 50-250 Mc/s.



Component Bridge Type B.121

A moderately priced 50 c/s instrument with a very wide range, capable of 3-terminal and a variety of in situ measurements.
R: 3Ω to 1000 mΩ, C: 1 pF to 1000 mF, L: 100 mH to 10,000 H.

Portable Wave Analyser Type A.321

To measure the relative levels of the components of a complex waveform over a range of 75 db between 50 c/s and 20 kc/s. Input impedance 100KΩ unbalanced or >25KΩ balanced. In transportable case as shown, or for standard 19″ mounting.

Wayne Kerr

Full details from:
THE WAYNE KERR LABORATORIES LIMITED
New Malden, Surrey, England

VOLTAGE STABILISERS

Cold cathode gas filled regulator tubes provide a sensibly constant output voltage from a source of supply liable to fluctuation, and under conditions of variable load, within certain limits dependent on the rating of the tube. They may also be used in cascade to obtain still greater reduction of output voltage fluctuations and in combinations of series and cascade connection.

Type	Base	Dimensions (*maximum*)		Striking Voltage (*maximum*)	Operating Voltage	Ignition Electrode Voltage	Ignition Electrode Resistance (Megohms)	Maximum Tube Current	Minimum Tube Current	Regulation over Current Range (Volts)	American Equivalent	CV Number
		Length mm.	Diameter mm.									
QS. 75/20	B7G	54	19	110	75	—	—	20	2	6	—	284
QS. 75/60	B8G	80	30	117	75	—	—	60	5	5	—	434
QS. 92/10	BRITISH 4-PIN	85	33	140	92	—	—	10	1	5	—	188
QS. 95/10	B7G	54	19	110	95	150	0.25	10	2	5	—	286
QS. 108/45	B8G	80	30	120	108	150	0.1	45	5	5	—	422
QS. 150/15	B7G	54	19	170	150	240	0.25	15	2	5	—	287
QS. 150/40	I.O.	105	39.5	180	150	—	—	40	5	5.5	OD3	216
QS. 150/45	B8G	80	30	170	150	200	0.1	45	5	5	—	395
QS. 1200	B7G	54	19	180	150	—	—	15	5	3	—	2225
QS. 1201	FLYING LEADS	80	19	110	75	—	—	15	2	4.5	—	—
QS. 1202	FLYING LEADS	80	19	133	108	—	—	15	2	4.5	—	—
QS. 1203	FLYING LEADS	80	19	180	150	—	—	15	2	4.5	—	—
QS. 1204	B7G	54	19	133	108	—	—	15	2	4.5	—	—
QS. 1205	I.O.	105	39.5	105	75	—	—	40	5	6.5	OA3	3798
QS. 1206	I.O.	105	39.5	133	108	—	—	40	5	5.5	OC3	686
QS. 1207	B7G	67	19	185	150	—	—	30	5	2.0	OA2	1832
QS. 1208	B7G	67	19	133	108	—	—	30	5	2.0	OB2	1833
HIGH STABILITY TUBE												
QS. 83/3	B7G	54	19	130	83	—	—	5	1	0.6	5651	449

RADIO FREQUENCY HEATING VALVES

English Electric Valve Company has developed two valves to meet the urgent needs of Radio Frequency Heating. They have been specially designed for this purpose and may be obtained in either air cooled or water cooled versions.

DATA

	BR 1102 BW 1102	BR 1103 BW 1103
Filament Voltage*	8.2 V	6.0 V
Filament Current (nominal)	230 A†	120 A‡
Peak Usable Cathode Current	45 A	16 A
Anode Voltage (D.C.)	12 kV max.	8.5 kV max.
Anode Dissipation	20 kW max.	10.0 kW max.
Grid Dissipation	1 kW max.	600W max.
Amplification Factor (at Va=9.0 KV, Ia=1.5 A)	42	
Amplification Factor (at Ea=5.0 KV, Ia=1.0A)		25
Mutual Conductance (at Va=9.0 KV, Ia=1.5 A)	20 mA/V	
Mutual Conductance (at Ea=5.0 KV, Ia=1.0 A)		8.3 mA/V
Operating Frequency (for full ratings)	50 mc/s max.	100 mc/s
TYPICAL OPERATING CONDITIONS (OSCILLATOR)		
Filament Volts	8.2 V	6.0 V
Anode Volts (D.C.)	12 kV	8.5 kV
Anode Current (D.C.)	5.5 A	2.75 A
Grid Current (D.C.)	1.4 A	0.75 A
Grid Volts (D.C.)	—740 V	—510 V
Grid Resistance	530 ohms	670 ohms
Anode + Grid Dissipation	17.5 kW	8 kW
Power Output	47.5 kW	15 kW

*Thoriated Tungsten Filament.

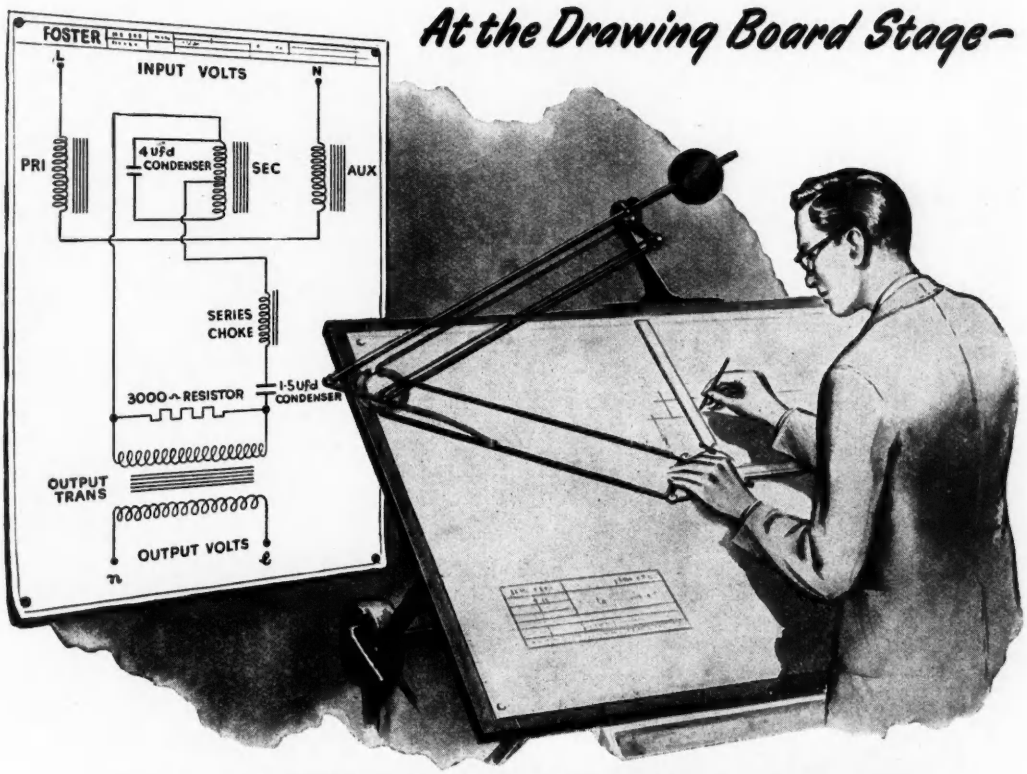
†*The starting filament current must not exceed 525 A, even momentarily, at any time.*

‡*The starting filament current must not exceed 260 A, even momentarily, at any time.*

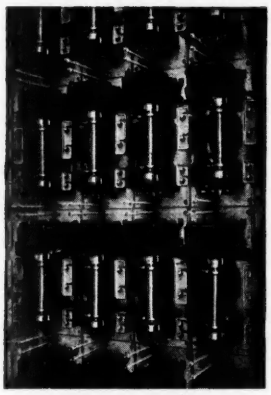
ENGLISH ELECTRIC VALVE COMPANY LIMITED

WATERHOUSE LANE, CHELMSFORD, ESSEX

At the Drawing Board Stage–



–plan the **'STABILISED POWER SOURCE'** *of your Equipment...*



FOSTER Engineers will be pleased to help. Hidden away in much electrical apparatus is a Foster "C.V." maintaining the characteristics so vital to research processing and indeed, every industrial application. Foster "C.V.s'" are also used in Traffic Light Signals, Radar Control Circuits, Navigational Radio Beacons Air and Sea, and a wide variety of services in the armed forces. Our picture shows a batch of Foster "C.V.s'" designed to suit a customer's particular requirements.

FOSTER

CONSTANT VOLTAGE TRANSFORMERS

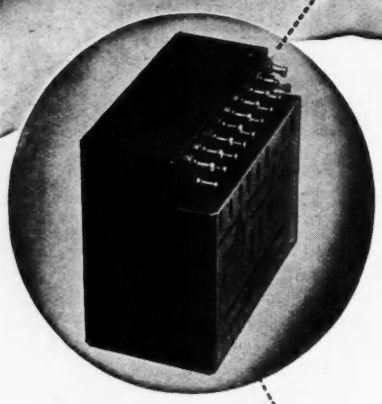
BUILT-IN COMPONENTS

It pays to solve Voltage Problems before they happen!

FOSTER TRANSFORMERS LTD SOUTH WIMBLEDON LONDON S.W.19

A 'LANCASHIRE DYNAMO HOLDINGS' COMPANY

VR/2



ULTRA SARAH is a complete system providing means whereby the location of wrecked personnel may be achieved with speed and certainty. Its use of powerful radio signals permits economical search from both the surface of the sea and the air. The system provides positive location of any number of persons even in conditions of total darkness or fog.

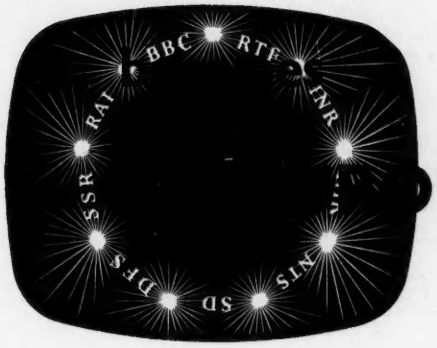
To match the miniature technique which Ultra designers adopted for SARAH, this compact Leocast Transformer was specially 'tailored' by Gresham engineers, who virtually succeeded in 'getting a quart into a pint pot' retaining, of course, all the reliability which is inherent in Gresham Transformers.

To Every Transformer Problem
There is a GRESHAM *Answer*

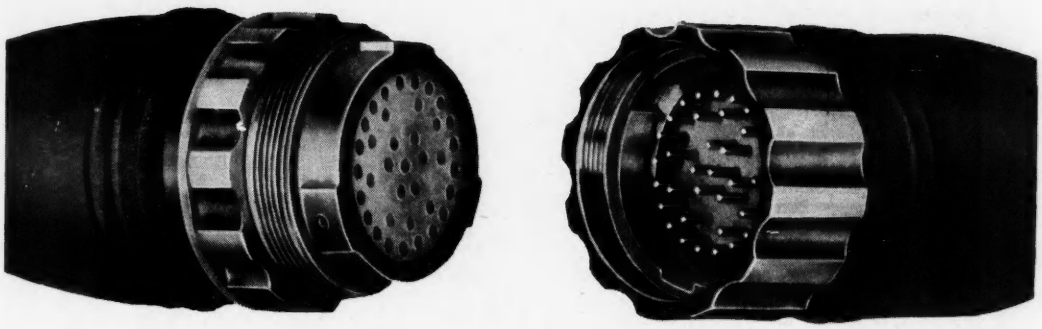
HANWORTH **GRESHAM** MIDDLESEX
TRANSFORMERS LTD

BRITAIN'S LARGEST INDEPENDENT TRANSFORMER MAKERS

TELEVISION



VISION



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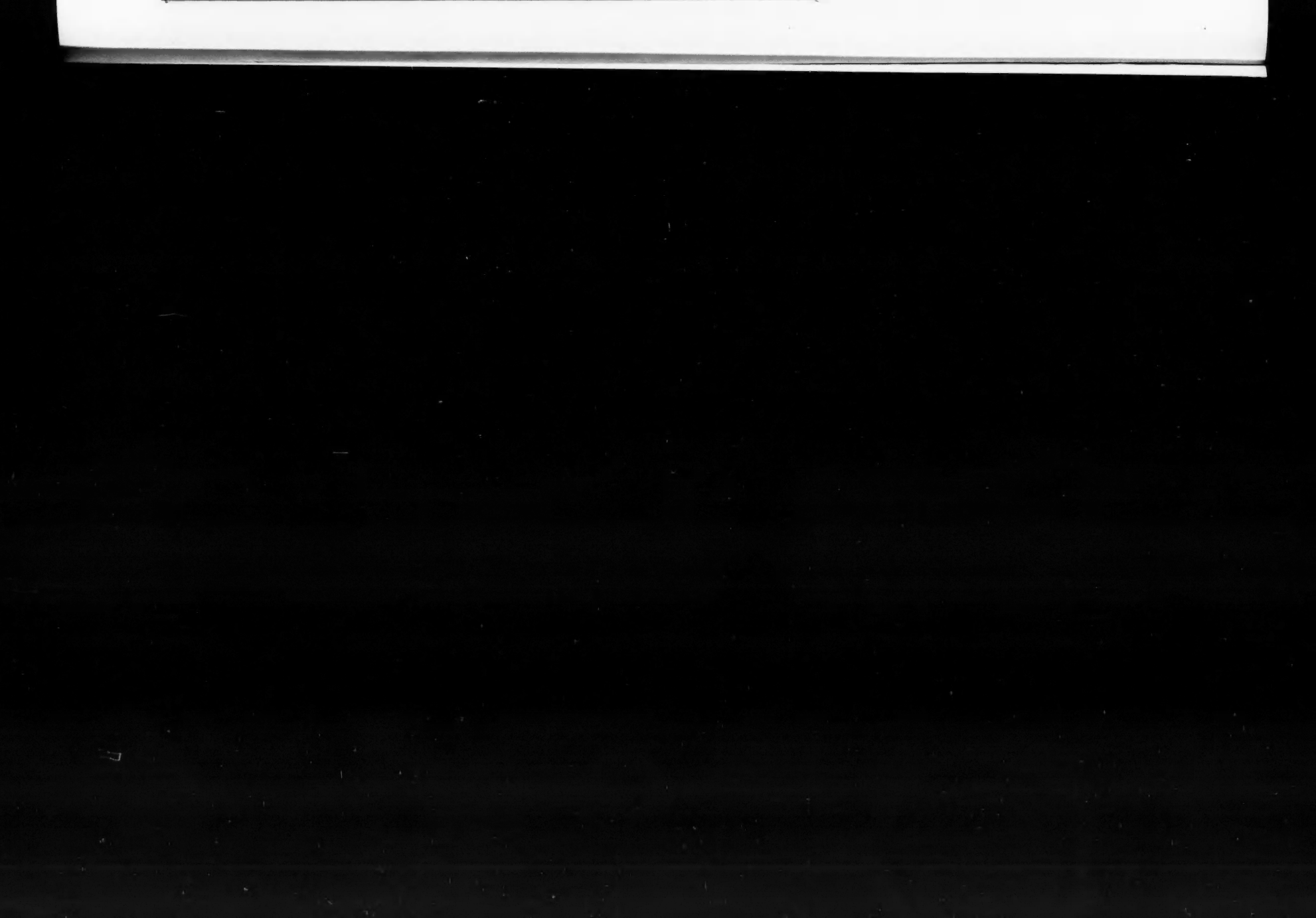

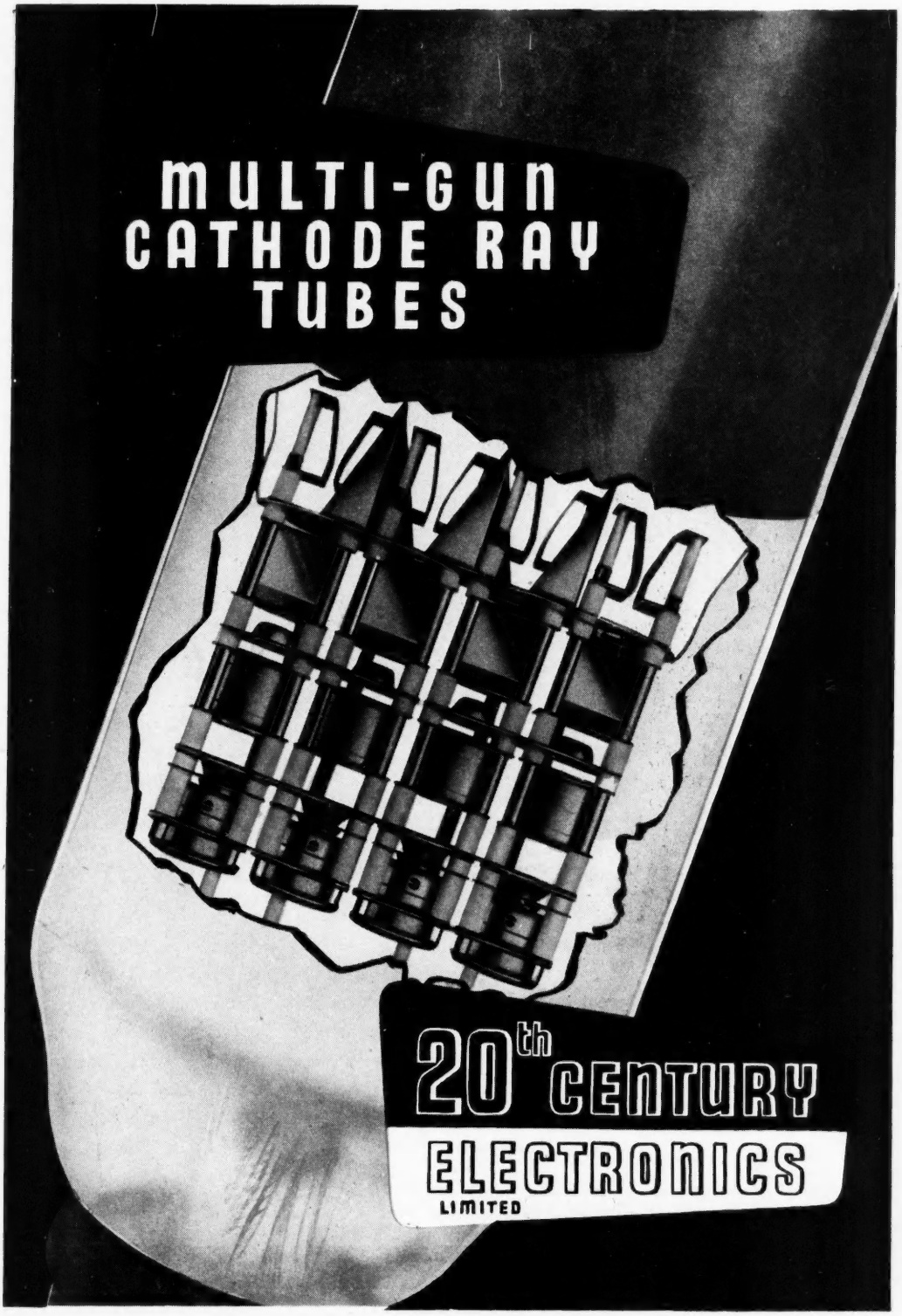

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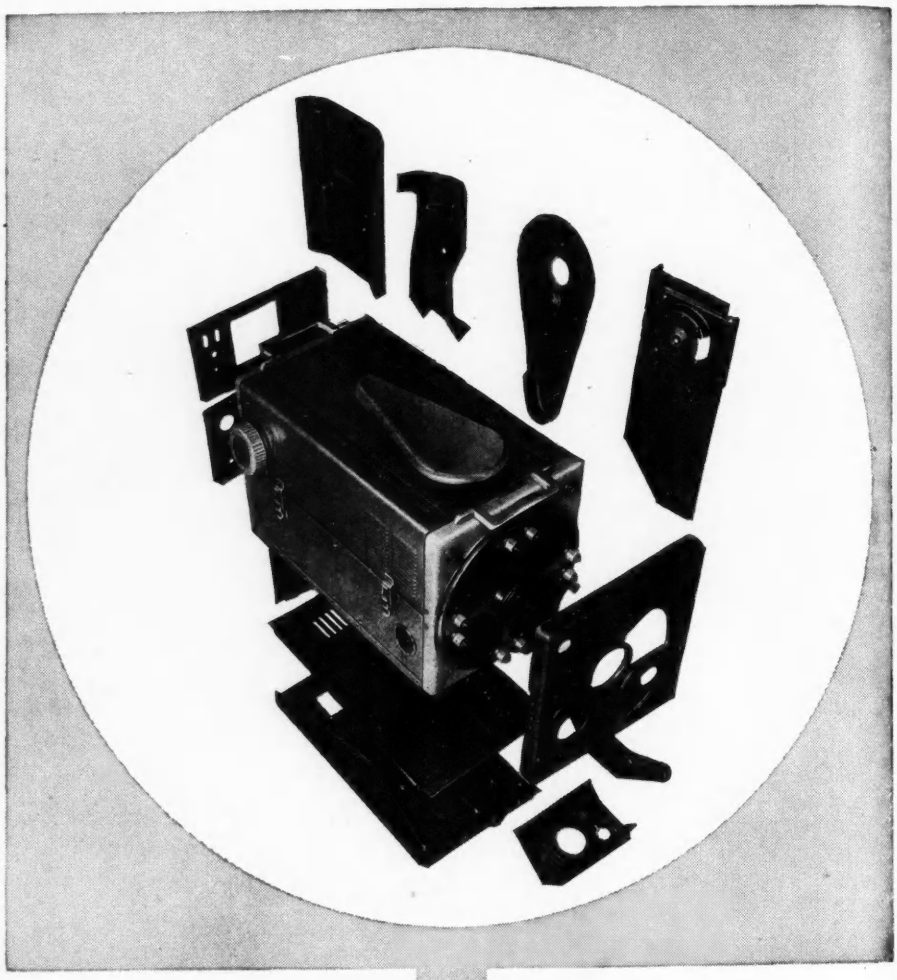

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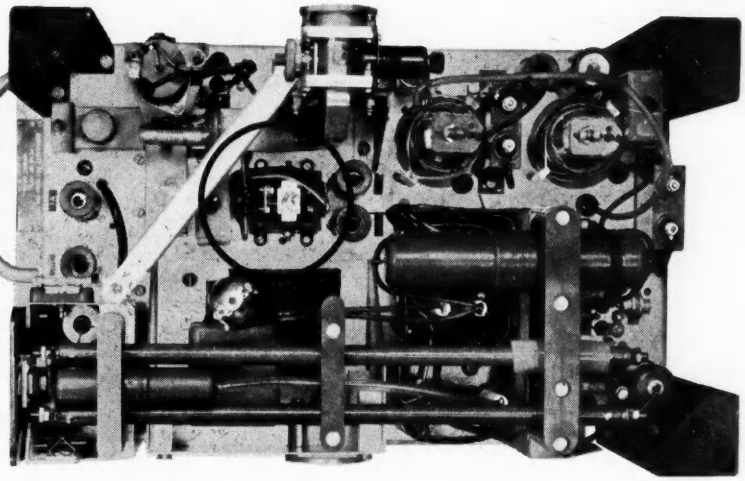
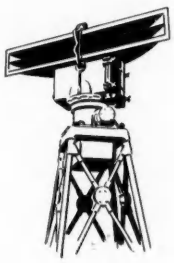


SUNVIC TIME DELAY SWITCHES



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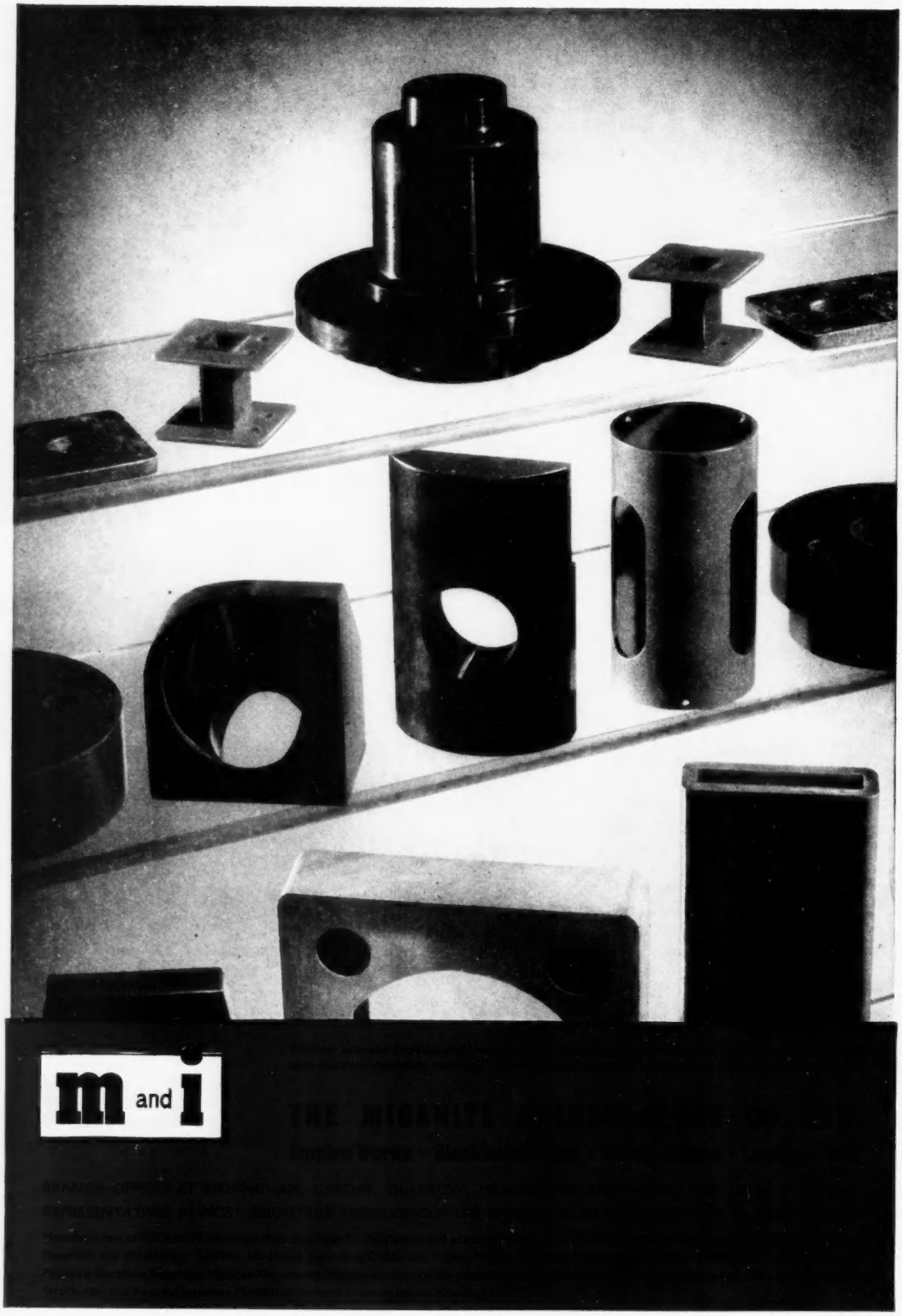
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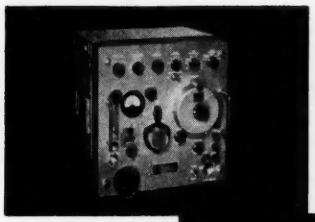
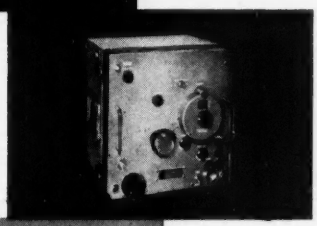
12,800 TO 50,000 MC

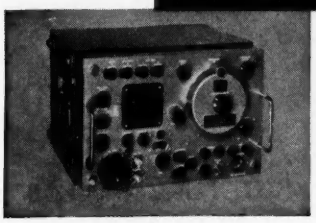
integrated equipment for Extremely High Frequencies



SIGNAL GENERATORS



SIGNAL SOURCES



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This new line of Signal Generators, Signal Sources, and Spectrum Analyzers is designed to save engineering manhours in the laboratory and on production lines—obviating experimental test set-ups.

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	SIGNAL GENERATORS		SIGNAL SOURCES		SPECTRUM ANALYZERS		
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12.8 to 17.5 KMC	SG 1218	—10 DBM	SS 1218	15 mw	SA 1218	—70 DBM	30 MC
15.75 to 16.25 KMC	SG 1516*	—6 DBM	SS 1516	5 mw	SA 1516	—70 DBM	45 MC
16.25 to 16.75 KMC	SG 1617*	—6 DBM	SS 1617	5 mw	SA 1617	—70 DBM	45 MC
18.0 to 22.0 KMC	SG 1822	—10 DBM	SS 1822	10 mw	SA 1822	—60 DBM	40 MC
22.0 to 25.0 KMC	SG 2225	—10 DBM	SS 2225	10 mw	SA 2225	—60 DBM	40 MC
24.7 to 27.5 KMC	SG 2427	—10 DBM	SS 2427	10 mw	SA 2427	—60 DBM	40 MC
27.27 to 30.0 KMC	SG 2730	—10 DBM	SS 2730	10 mw	SA 2730	—60 DBM	45 MC
29.7 to 33.52 KMC	SG 3033	—10 DBM	SS 3033	10 mw	SA 3033	—60 DBM	45 MC
33.52 to 36.25 KMC	SG 3336	—10 DBM	SS 3336	9 mw	SA 3336	—50 DBM	45 MC
35.1 to 39.7 KMC	SG 3540	—10 DBM	SS 3540	5 mw	SA 3540	—50 DBM	45 MC
37.1 to 42.6 KMC	External Source Power Measurement Range: +6 to +30 DBM Accuracy with Correction: ±2 DB		SS 3742	Approx. 3 mw			
41.7 to 50.0 KMC			SS 4150	Approx. 3 mw			

I.F. Gain Control: 0 to 40 DB

I.F. Band Width: 50 KC

Sweep Frequency: 5 to 40 CPS

Modulation: All units except the SG 1516* and SG 1617* can be modulated as follows:

1. Internal
   1000 CPS Square Wave
2. External
   a. Pulse
      Pulse Width: 0.5 to 10 Microseconds
      PRF: 100 to 10,000 CPS
      Pulse Amplitude: 10 volts Pk to Pk Min.
      Polarity: Positive
   b. Sawtooth or Sinusoidal
      Frequency: 100 to 10,000 CPS
      Amplitude: 15 Volts RMS Min.

*Internal variable pulse and FM modulation

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We are proud, therefore, to be helping in our own small way to ensure the efficient performance of the Mk. 12 aircraft turn and slip indicator shown. B.M.B. ball bearings are fitted to the gyro athwartship axis and give unfailing performance under varying conditions of speed and temperature.

If you make instruments, small mechanisms or machines, B.M.B. Super-Precision ball bearings will ensure greatly increased efficiency at reasonable cost.

Technical literature illustrating our products will be sent upon request.

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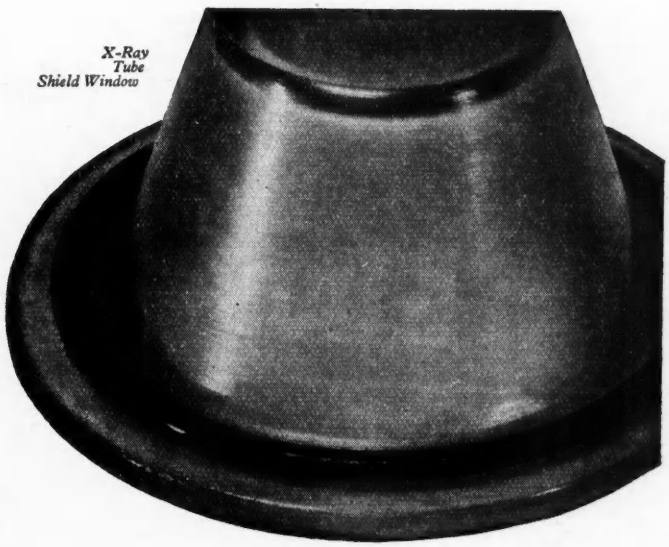

X-Ray Tube Shield Window

Cast in ARALDITE

For moulding, potting or sealing purposes, no resin can compare with 'Araldite'. Added to remarkable electrical and mechanical qualities, it offers outstanding adhesion to metals, while shrinkage in setting is exceptionally low. 'Araldite' resists high temperatures, humidity and corrosive agents and fulfils the Services specification for sealing and potting electrical equipment.

Our illustrations are of three components from Pantak Ltd., Slough, makers of X-ray equipment. Such mouldings must combine high mechanical strength with the capacity to withstand high voltages. They exemplify the versatility of 'Araldite' epoxy resins.

Cable Socket casting incorporating brass insert

These are the new Epoxies!

'Araldite' (regd.) epoxy resins are obtainable in the following forms:—

- *Hot and cold setting adhesives for metals and most other materials in common use.*
- *Casting Resins for the electrical, mechanical and chemical engineering industries.*
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Full details will be sent gladly on request.

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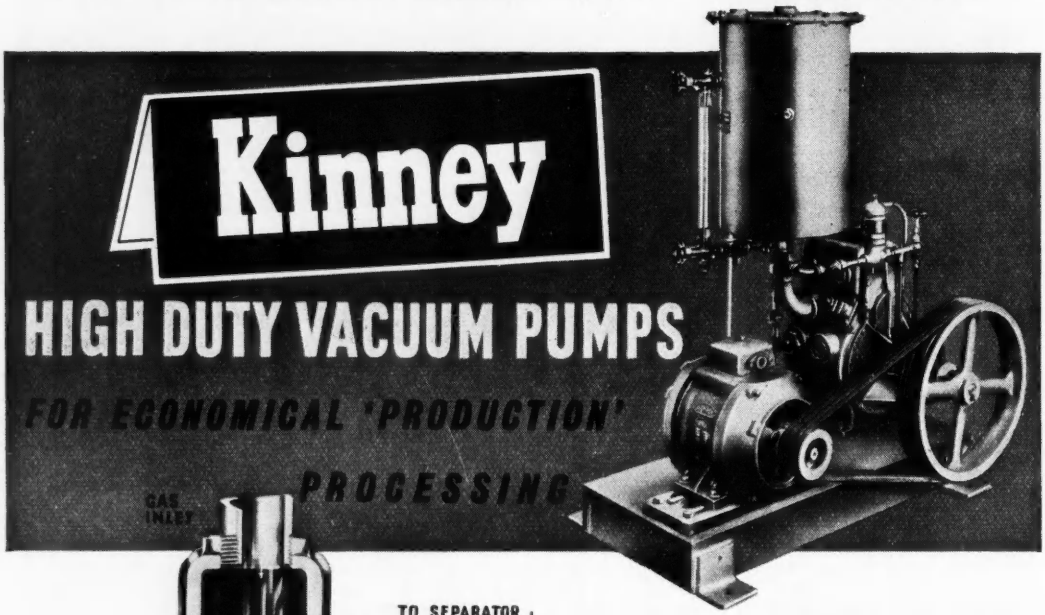
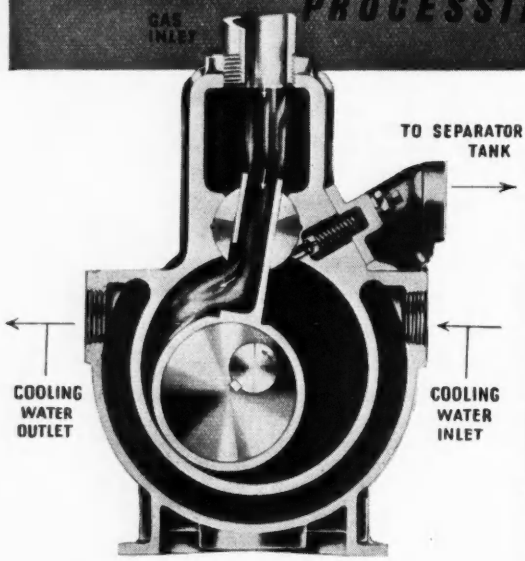
Kinney

HIGH DUTY VACUUM PUMPS

FOR ECONOMICAL 'PRODUCTION' PROCESSING





OPERATING CYCLE OF KINNEY VACUUM PUMP

The plunger, moving in the direction of the arrow, rapidly creates space into which gas is admitted through the inlet valve. Simultaneously, gas previously trapped is being compressed. When the plunger reaches its highest position, air or gas and surplus sealing oil is expelled through the outlet valve and nozzle into the oil separator tank. There, the oil is retained and the air or gas discharged to the atmosphere. Further movement of the plunger closes the inlet valve and completes the cycle of operation.

KINNEY VACUUM PUMPS SHOW THE WAY

Has it ever occurred to you that Kinney Vacuum Pumps might well solve *your* problems? Cathode ray tubes, electric lamps, coated lenses and mirrors, drugs, foodstuffs, coated foils, condenser papers, electrical components—these are a few of the products now being made quicker, better and more profitably, thanks to Kinney Vacuum Pumps. Models VSD and DVD single stage (10 microns absolute pressure or better); model CVM double stage (0.5 micron or better), displacements 15 to 700 c.f.m. Bulletins 101 and 104 tell you all about them.

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London Office : 3rd Floor, 9 Victoria Street, London, S.W.1.
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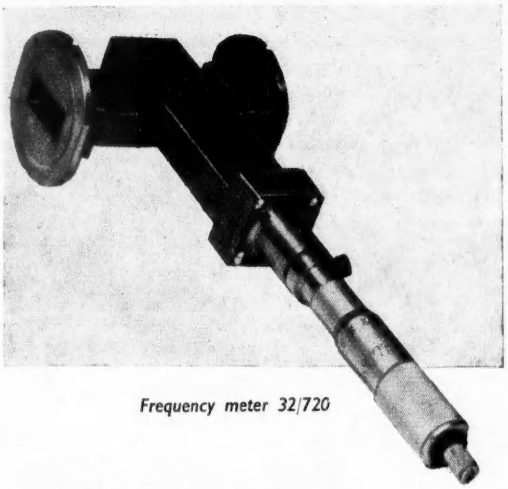
M.I.L. Frequency meter for accurate routine readings



Frequency meter 32/720

RANGE 8,500 to 10,100 Mc/s. A calibration chart is supplied with each instrument.

"Q" FACTOR 3,000 approximately, and fairly consistent over the frequency range.

SENSITIVITY This is such that upon resonance the wavemeter introduces an absorption dip of approximately 20%. This is very consistent over the frequency range.

THE PISTON is one of the rectangular re-entrant choke type. This meter is primarily intended for routine work and teaching purposes where an inexpensive instrument is usually desired. It is available for early delivery.

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Electronic Engineering

Incorporating ELECTRONICS, TELEVISION and SHORT WAVE WORLD.
Managing Editor H. G. Foster M.Sc. M.I.E.E.

Vol. XXVI DECEMBER 1954 No. 322

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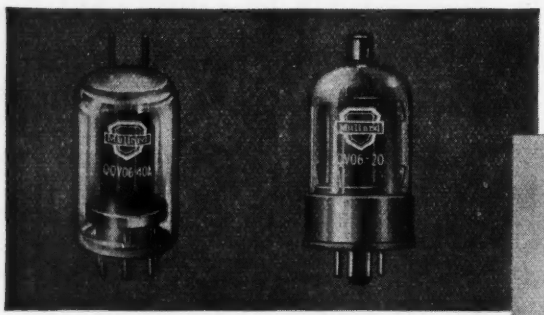
V.H.F. POWER TETRODES

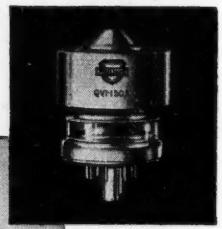
FOR F.M. & TELEVISION TRANSMITTERS

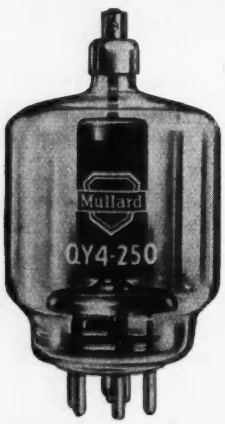
Transmitter designers are now offered a complete range of V.H.F. tetrodes by Mullard.

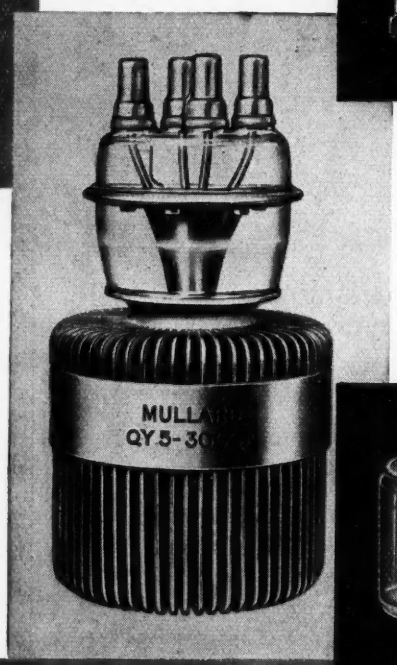
These high efficiency, high gain tetrodes make possible the design of transmitters with fewer valves and, consequently, reduced initial cost.

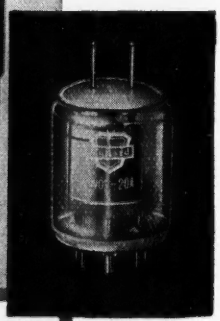
The higher overall efficiency of equipments fitted with Mullard tetrodes results in lower running expenses—a factor in the growing popularity of these valves in the world market. Further details of these tetrodes and other Mullard valves and tubes may be readily obtained from the address below.











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MULLARD TYPE No.	AMERICAN TYPE No.	CV TYPE No.	DESCRIPTION	BASE	HEATER (V)	HEATER (A)	V_a max. (V)	P_a max. (W)	TYPICAL LOAD POWERS AND FREQUENCIES (W)	TYPICAL LOAD POWERS AND FREQUENCIES (Mc/s)
QV06-20	6146	CV3523	V.H.F. Power Tetrode	Octal	6·3	1·25	600	20	42 20	60 175
QQV03-20A	6252	CV2799	V.H.F. Power double Tetrode	B7A	6·3 12·6	1·3 0·65	600	2x10	39 15	200 600
QQV06-40A	5894A	CV2797	V.H.F. Power double Tetrode	B7A	6·3 12·6	1·8 0·9	600	2x20	72 45	200 500
QY3-125	4-125A	CV2130	V.H.F. Power Tetrode	B5F	5·0	6·5	3000	125	300	120
QY4-250	4-250A	CV2131	V.H.F. Power Tetrode	B5F	5·0	14	4000	250	800	75
QV1-150A	4X-150A	CV2519	V.H.F. Power Tetrode	B8F	6·0	2·6	1250	150	156 112	165 500
QY5-3000A	6076	CV6076	V.H.F. Power Tetrode	Special 4-pin	6·3	32·5	5000	3000	3300 *3500	75 220

* 2 Valves in push-pull. Television service.

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MULLARD LTD., COMMUNICATIONS & INDUSTRIAL VALVE DEPT., CENTURY HOUSE, SHAFTESBURY AVENUE, LONDON, W.C.2

MVT.169

ELECTRONIC ENGINEERING

VOL. XXVI No. 322

DECEMBER 1954

Commentary

IN our last issue comment was made on the Jubilee of the invention of the thermionic valve and a brief account was published of the life and work of the late Sir Ambrose Fleming. Such anniversaries provide an occasion for a review of historical development and, in the better perspective which the passage of time makes possible, it not infrequently happens that there are lessons to be learned therefrom. For thirty years or more, Fleming has been widely acknowledged, at least in this country, as the inventor of the valve, but scientific history has so often been distorted by commercial interests, by the need to establish patent claims or by the needs of publicity that it is not unreasonable at least to enquire into the circumstances in which Fleming's invention was made. At the risk of being accused of detracting from the merit of Fleming's invention, let us briefly review the background.

Fleming's work in this field had begun as early as 1882 when, at the age of 32, he had joined the Edison Electric Light Company and become engaged in the many problems then awaiting solution with the early electric lamps. Among these problems was the prevention of the blackening of the inside of the bulbs and, in particular, the investigation of the causes of the clear white line which was sometimes noticed on the inside and which seemed to be a shadow of one leg of the filament. Edison himself carried out some experiments on the subject in 1884, in the course of which he sealed a sheet of metal foil inside a lamp and observed that if this electrode was connected to the positive leg of the filament through a sensitive galvanometer a small current could be detected but that no current flowed if it was connected to the negative leg.

During a period of eight or ten years, Fleming carried out many researches in this field and, in 1889, he had constructed a whole series of special lamps with variously shaped electrodes within the bulb. He thus became intimately familiar with the conditions under which a current could pass from the heated filament to a nearby anode. Even if the exact mechanism of thermionic emission was not fully understood—the electron was not discovered until 1897—Fleming's work on the Edison effect in 1889 had clearly shown that a current could only pass between filament and anode if the anode was positive in respect to the filament. He knew, in fact, in 1889 that an electric lamp with an electrode inside would act as a rectifier of alternating current.

In 1900, Fleming joined the Marconi Company as a consultant and he was largely responsible for the design of the transmitter at Poldhu, from which the first wireless signals were sent across the Atlantic. Intimately aware of the capricious behaviour of the coherer detectors then in use and of the urgent need for a more reliable detector, it seems remarkable that it was not until October, 1904, that he thought of trying one of his experimental lamps, made fifteen years earlier, as a rectifier of high frequency currents. The experiment was immediately successful—the Fleming Oscillation Valve was born—but if it is surprising that the idea should not have occurred to Fleming earlier, it is still more remarkable that he should have made so little effort subsequently to develop and improve on his discovery. With all the background of his previous work on the Edison Effect to guide him and with all the facilities that he had available, it does seem incredible that he should have done so little towards its further development.

The fact is, of course, that Fleming had invented nothing new ; all that he had done was to apply a known device to a new application and since the Fleming valve was no more sensitive than the magnetic detector which had been introduced two years earlier, it is not surprising that it was regarded at the time as merely an interesting but unimportant alternative.

Fleming's application was a novel one—but all wireless telegraphy was a novelty in those days. Nevertheless, if the Patent Office examiners had been able to view his application with the perspective we can apply today, we cannot help wondering whether they would have granted him a Patent at all. Provocative though this thought may be, it is a fact that Fleming's Patent of 1904 was declared invalid by the Supreme Court of the U.S.A. as recently as 1943 on the grounds that he had applied for a patent for the valve as a rectifier of high-frequency oscillations without disclaiming its already known use as a low-frequency rectifier.

Why did it take Fleming so long to apply his experimental lamps to the detection of high-frequency oscillations ? Why, with all his background of experience in this field and all the resources at his command did he so completely neglect the subsequent development of the valve ? We may never know the answers to these questions but surely the moral is clear. Let every scientist who is called upon to work in some new field consider whether he has not some special knowledge gained from past experience to apply and develop to advantage in his new surroundings and, having found some new and useful application, let him pursue it, develop it and exploit it to its uttermost capacity.

Three-Phase High-speed Magnetic Amplifiers

By A. E. MAINE*, A.R.Ae.S., A.Brit.I.R.E.

The article describes the extension of the principles of "Half-Wave" High-Speed Magnetic Amplifiers to 3-phase circuits. It is shown that there are many arrangements possible for 3-phase operation and these offer scope for continued development and application especially in the field of high-speed, high-power control systems. A 50c/s multi-stage unit of this type is described giving a power output of about 1kW, and used for supplying the armature requirements of a ¾ h.p. D.C. motor forming part of a fast acting servo system. The article is based largely upon the results of an experimental study, and represents early work carried out in a relatively new branch of the magnetic amplifier field.

SEVERAL papers have appeared in the literature over the course of the last few years dealing with high speed magnetic amplifiers of the "half-wave" type. Such amplifiers fall naturally into a class of their own since they possess several well-defined features. Probably their most important characteristic is their relatively fast response to a change of input signal. Here we find that full response can be obtained within the time of half a cycle of the A.C. excitation frequency. This fast action points significantly to the basic mechanism involved, i.e. a system wherein the control intelligence is impressed in a magnetic core during one half cycle (sampling) and acted upon in the half cycle following (gating). The medium involved in the process is, of course, the flux in the core, which latter is assumed to be highly remanent and sharply saturating.

The volt-seconds storage of a core is directly proportional to the maximum (knee-to-knee) flux swing and the number of turns, and usually this quantity is made to correspond to the voltage-time integral of the supply wave over one half cycle. It follows then, that if at the beginning of a gating period, the flux starting point is other than at the lower knee, a fraction of the applied voltage integral cannot be absorbed by the reactor, and must, therefore, appear across whatever impedance there is in the circuit. Load current consequently flows around the circuit, the reactor having substantially zero impedance in this interval.

The scheme of control may now be simply stated. An input signal is allowed to set the flux level in a "negative" direction during sampling. This level determines the angular instant in the following half cycle, with the flux going positive, when the reactor "fires". Since only magnetizing currents need flow during the sampling half cycle, and load currents limited only by the thermal rating of the reactor are possible during gating, it follows that the simple system described acts as a power amplifier. The separation of the two processes in time is accomplished by means of rectifiers connected in appropriate directions to the control and load circuits, both of which contain an A.C. source. The auxiliary A.C. voltage acting in the control circuit provides the necessary core magnetization to ensure full "re-set" of the flux during sampling, and therefore minimum load current, when the signal voltage is zero. It is to be noticed that during the sampling period, the control voltage is applied in series opposition to the auxiliary voltage and it is the difference between these which determines the re-set flux level, and subsequently the average value of the load voltage. A simple amplifier arrangement of the sort described is shown in Fig. 1(a) and represents a foundation for the development of more elaborate arrangements.

* *Servo Systems Department, The de Havilland Propeller Co. Ltd.*

The Three-Phase Connexion

A "full-wave" single-phase amplifier may be set out in bridge form as shown in Fig. 1(b). Here, four cores are used and because two coils are effectively in series in the two branches, each reactor is designed to absorb only one half of the applied voltage integral. Examining the circuit, it is evident that with the polarities given cores 1 and 4 are in a gating period while cores 2 and 3 are being re-set. Inverting

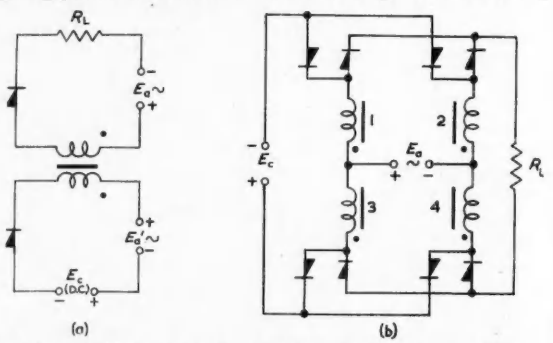


Fig. 1(a). Simple half-wave single core amplifier. (b). Bridge connected full-wave amplifier

the polarities of the supply terminals for the next half cycle, shows that the pairs of reactors exchange their operation. The load voltage will evidently be similar in form to that delivered by a single-phase grid controlled rectifier.

The functions described above can be secured with a more refined circuit but that shown in Fig. 1(b) has been deliberately chosen since it leads easily to the introduction of amplifiers for 3-phase operation. Here we add a third branch to the basic bridge and join its mid-point to the third phase of the supply. The new circuit is illustrated in Fig. 2(a) and this constitutes a full-wave three-phase amplifier possessing the usual half-cycle response and giving a voltage gain of unity.

An experimental amplifier of this sort operating at 400c/s and employing 1½in square H.C.R. laminations has been built and used to verify the dynamic response. The output power was about 10 watts and germanium junction diodes were used throughout. Photographs of the output voltage waveform during the application of step changes of control voltage showed clearly the half cycle response of the amplifier. The harmonic response tests yielded interesting results and suggest that the device behaves substantially as a pure time delay of $1/2f$ seconds. The amplitude ratio is shown in Fig. 3 and exhibits an unexplained rise before the fall away at approximately 20db/decade. The phase measurement

shown in the inset was obtained by means of a Lissajous figure derived from the input and output voltages. The technique consisted of raising the test signal frequency and noting the points at which successive 90° phase shifts were obtained. It might be mentioned that a large number of " beats " were observed above a signal frequency of 400c/s, these being due to modulation products of the signal and sampling frequencies and their harmonics. In contrast to the single-phase version the beats were found to be of generally small amplitude. It appears therefore that the dynamics of the three-phase version differ somewhat from those of the single-phase arrangement and it is perhaps remarkable that the amplifier offers considerable response to signal frequencies well above that of the excitation source.

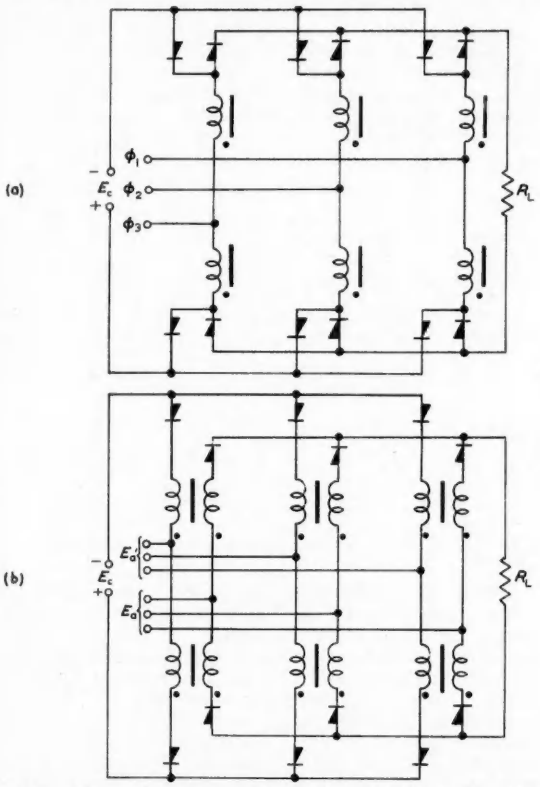


Fig. 2(a). Full-wave, three-phase magnetic amplifier. (b). Full-wave, three-phase amplifier with separate control coils

Often it is desirable to achieve galvanic isolation between the load and control circuits and, in addition, a voltage gain greater than unity may be required. Both of these needs may be fulfilled by the arrangement of Fig. 2(b) which employs double wound reactors. In this case a second three-phase re-setting supply is needed having a voltage $1/N$ of that of the load circuit, where N is the ratio between load and control turns. Both of the amplifiers described may be " resistance " or voltage controlled. In the first case a variable resistance is connected between the control terminals, and hence the magnetizing current flows through it during the sampling periods. The voltage developed across the resistance is not available for influencing the core flux, hence the greater the resistance, the less the re-setting action and the greater the load voltage. This type of operation is not often employed, voltage control being generally more useful. In this case the control source must have a sufficiently low impedance to prevent the loss of a significant amount of voltage from the reactors. The source voltage may take the form of (a) pure D.C., (b) three-phase full-wave, rectified and variable amplitude, or (c) three-phase, fixed maximum amplitude, rectified and variable conduction angle, e.g. the output voltage of a similar amplifier.

It will have been noticed that the amplifier configurations discussed so far follow the patterns of well-known rectifier

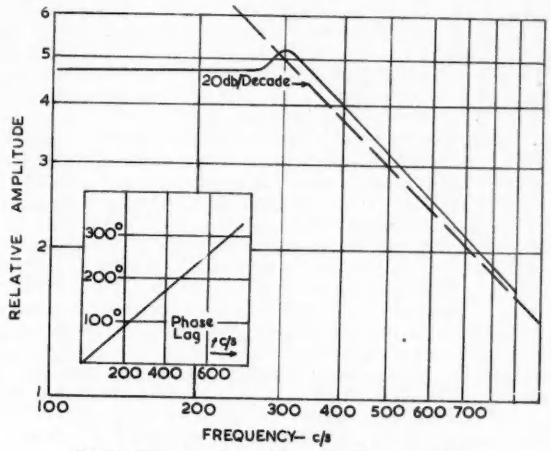


Fig. 3. Dynamic response of three-phase full-wave amplifier

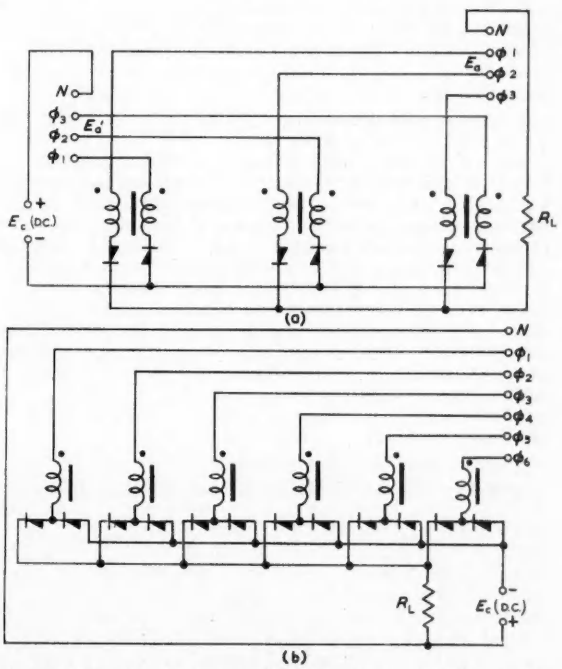


Fig. 4(a). Three-phase, half-wave amplifier with separate control coils. (b) Six-phase, half-wave amplifier

arrangements and one might expect other rectifier connexions to be equally applicable in this respect. This is indeed the case, and it is easy, for example, to set out half-wave versions such as those shown in Fig. 4. These amplifiers are perfectly sound in all respects but suffer the dual disadvantages that a neutral line is required, and the average load voltage, other things being equal, is reduced. In fact it might be said that the important features of the rectifier arrangements apply equally to high-speed amplifiers based upon them.

Core Materials and Constant M.M.F. Bias

Since the main application of the multi-phase amplifier is undoubtedly in the medium and high power fields, it follows that relatively large reactors with heavy cores are normally required. For the best possible results nickel-iron alloys, e.g. Permalloy " F " or H.C.R. are needed for the core construction and if such materials are used the reactors are liable to be rather costly. Reasonable alternatives to the nickel-iron group may be found in the grain oriented silicon steels, and type 62 Crystalloy is perhaps the most promising material in this category, at least for mains frequency operation. This material has a peak flux density of about 13 kilogauss and close upon 95 per cent remanence. In comparison with H.C.R. the hysteresis loop is very fat and the permeability at the flanks considerably smaller. From this it is evident that the standing control currents are relatively large and the power gain reduced. A worthwhile improvement may, however, be brought about by means of supplying the core with a constant M.M.F. bias. This has the effect of moving the hysteresis loop bodily along the H axis, the excursion being terminated when remanence loss becomes significant. At this point it is found that the control circuit magnetizing current is appreciably reduced, whereas the magnetizing current in the pre-firing gating period is correspondingly raised. The scheme serves the purpose of reducing the control current but renders the amplifier more sensitive to load rectifier leakage. In practice the required bias is obtained by joining a source of direct current to auxiliary windings on the reactors, the high circuit impedance ensures that alternating components induced into the bias windings are ineffective in altering the core state. Experiments show that a reduction of control current by a factor of two or three is possible.

Core Balance

For best results with the three-phase circuits, it is desirable to use sets of balanced cores in the amplifiers. In the case of laminated reactors, balance may be readily obtained by means of adjusting the number of laminations in each core so that they all saturate at the same value of applied voltage. Matters are not so straightforward if the spiral tape core construction is used, and here it becomes necessary to select similar cores and perhaps trim the number of turns on each. If large quantities of such cores are required it would be desirable to test each core before winding and make appropriate adjustments to the number of turns during winding. The balancing procedure eliminates departures from linearity of the voltage transfer characteristic, particularly in the region of low output voltage.

Rectifiers

The rectifiers employed in Ramey[1-5] type half-wave amplifiers have a dominating effect on overall performance. This is especially apparent when using rectangular loop nickel-iron core materials. Spurious re-setting will always occur if the reverse leakage current is equal to or greater than half the width of the hysteresis loop when the H axis is calibrated in current for a given number of turns. To underline the importance of this point the case may be quoted of a high power amplifier designed to yield a maximum load current of 2A where the " $\frac{1}{2}$-loop " value of magnetizing current was only 2mA. In cases of this sort it is necessary to either halve the manufacturers' voltage ratings for selenium rectifiers or possibly to use modified forms of amplifiers such as those proposed by Scorgie and House. Increasing the number of rectifier plates involves a worsening of overall efficiency which may drop well below 70 per cent. In high power applications the loss is undesirable to say the least and may well be serious. The capacitance of selenium rectifiers, even at power frequencies can be troublesome—in one case a 1kW 15A rectifier set was found to have a capacitance of 2μF per arm and this, too, produced unintentional reset thereby reducing the maximum output voltage. As a general rule, whether or not special circuit techniques are used it is desirable to work metal rectifiers at considerably reduced voltage ratings and to select stacks having the smallest possible leakage current. The control circuit rectifiers are somewhat less of a problem, especially as germanium junction units can usually be used here. These rectifiers in comparison with selenium types have very much improved characteristics and possess a high front to back ratio and very low forward power loss. Reviewing the whole question of rectifiers it seems that very much better units are needed if the potentialities of the circuits discussed are to be fully exploited. Large germanium[6] and silicon junction units may be promising in this respect.

Flux " Pre-Set " with Three-Phase Amplifiers

It has been stated previously that a highly remanent core material is necessary for the basic modes of action discussed. However, it is shown in a paper by House[7], that single-phase half-cycle response amplifiers may be constructed using core materials possessing zero remanence. Simply stated the necessary flux conditions are brought about by means of

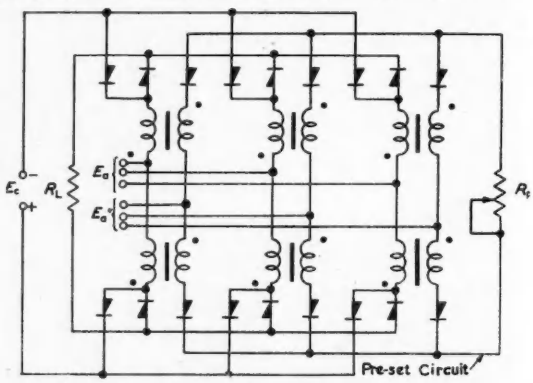


Fig. 5. Three-phase amplifier showing flux ' pre-set ' proposal

reversing the sense of the control coils, thus permitting an upward movement of the flux towards positive saturation during sampling. House describes the new operation as *pre-setting* and shows that the flux may indeed be set to any desired level by the onset of the gating period. It is also shown that partially remanent cores may be used under specified circumstances in arrangements which contain both re-set and pre-set circuits. A study of these proposals has indicated that such methods should be equally valid when applied to three-phase systems and hence it seems more likely that less refined core materials may be used successfully for large power applications. Furthermore, the spurious re-setting arising out of leaking main rectifiers can be largely off-set by these methods. A proposal showing the addition of flux pre-set to a three-phase circuit is given in Fig. 5. It is implied that only a relatively small remanence loss is involved, the pre-set circuit being adjusted to give the required amount of " flux-lift " to enable full output voltage to be achieved. Schemes of this sort are still under development.

The Three-Phase Amplifier with Negative Voltage Feedback

In the circuit types considered in the preceding paragraphs, a limitation to low-level signal working is imposed by the control rectifier characteristics which become unsatisfactory when the circuit voltages are small. The maximum voltage gain normally obtainable is usually determined by these considerations alone. Scorgie[8] has set out a means of overcoming this difficulty which consists of eliminating the control rectifiers altogether, and applying 100 per cent negative voltage feedback over the amplifier. The arrangement, which in some respects is more fundamental than

Ramey's schemes does not require an additional magnetizing source in the control circuit. In operation, the magnetizing voltage is obtained jointly by induced voltages from other non-fired cores while in their gating periods, and by the load voltage itself: the two components are furnished in time sequence. Such a scheme is applicable to the three-phase amplifier and a circuit modified in this way is shown in Fig. 6. It is to be noted that for a turns ratio of N (previously defined) the fraction of the load voltage required to give 100 per cent negative feedback is $1/N$, if the turns ratio is greater than unity, and the load appreciably inductive, difficulties arise since the arrangement becomes unstable, behaving as a second order system with only slight damping. A possible way out of this trouble is to wind the reactors with extra coils connected to form an auxiliary load circuit and deriving the feedback voltage from this.

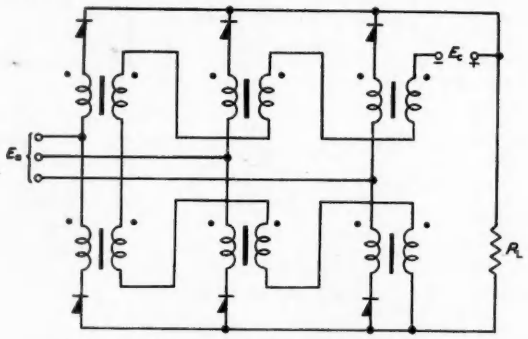


Fig. 6. Three-phase amplifier with negative voltage feedback

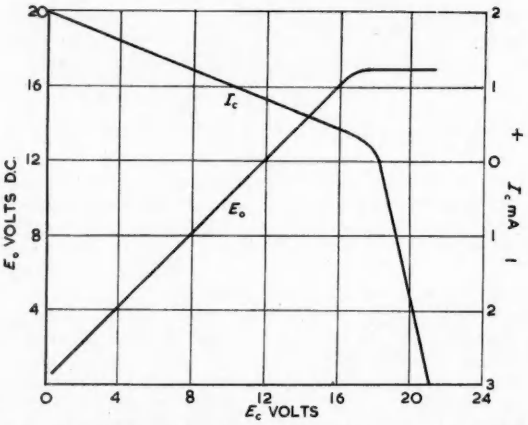


Fig. 7. Characteristics of three-phase amplifier with negative voltage feedback (H.C.R. cores)

The elimination of rectifiers from the control circuit serves a further important function in that it permits the control magnetizing current to assume any magnitude and direction necessary to support the flux conditions imposed by the applied voltages. As a consequence the amplifier maintains its essential features even when employing substantially non-remanent core materials. Fig. 7 shows the measured characteristics obtained from the circuit arrangement of Fig. 6 and employing laminated H.C.R. reactors. A duplicate experiment carried out but employing Mumetal cores showed that the form of the voltage transfer characteristic remained unchanged, but the control current reversed sign at a much lower value of control voltage. These results are important because, in common with the proposals of House they point the way to the use of lower grade core materials. It must be pointed out, however, that a rectangular loop material is generally to be preferred since the control current assumes a very simple form and the amplifier is amenable to the employment of M.M.F. bias and positive feedback schemes aimed at further increasing the gain.

The Three-Phase Amplifier with Positive Current Feedback

Elementary analysis of the half-wave amplifier suggests that if the power gain is raised by increasing the current gain, the half cycle response should be preserved. Such a proposition is put forth by Scorgie[7] and involves the use of positive current feedback. This scheme has been tried experimentally with the three-phase circuits, and appreciable increases in steady state gain observed. Fig. 8(a) shows the equivalent circuit of an arrangement wherein the load voltage is coupled back to the control circuit through a high-valued coupling resistance and the control source is shunted with a constant current. Fig. 8(b) shows the idealized construction yielding

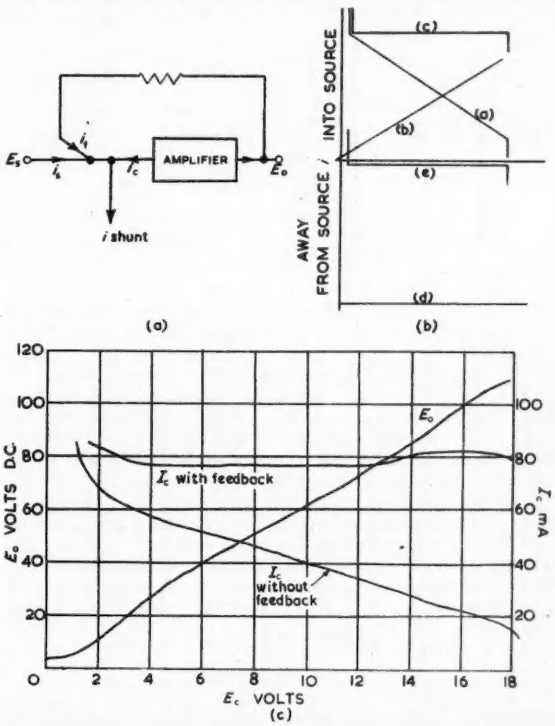


Fig. 8(a). Equivalent circuit of amplifier with positive current feedback. (b). Idealized construction showing effect of positive current feedback. (c). Measured characteristics of three-phase amplifier with positive current feedback

infinite power gain. Curve (a) is the typical form taken by the control current, and curve (b) the feedback current obtained from the load, and adjusted by the coupling resistor to have equal but opposite slope. Curve (c) is the sum of (a) and (b) and indicates the net core M.M.F. Curve (d) represents the constant current shunt. Finally, curve (e) shows the sum of (c) and (d) and is drawn displaced away from the horizontal axis only for reasons of pictorial clarity. Fig. 8(c) shows a practical characteristic obtained experimentally but without the constant current shunt. It is evident that the gain measured in terms of $\Delta I_1/\Delta I_C$ has been increased to infinity over a wide portion of the range. The amplifier used for the tests was the 400c/s unit previously mentioned. Investigation of the dynamics yielded the important result that the half-cycle response, with the current feedback was only obtainable when the signal source impedance was substantially zero. With realistic values of source impedance the control voltage is changed from its

proper value in the transient condition, due to the feedback, and the half-cycle response is lost. Apart from the use as an inter-stage amplifier, where the driving source impedance can be kept reasonably small, it is thought that the technique has rather limited usefulness.

Coupling Two or More Stages

The general order of power gain obtainable from the standard full-wave three-phase amplifier is some hundreds and may reach 1 000, but hardly any more. This is usually too small for practical purposes and so a two- or three-stage design may be required. The question of coupling amplifiers of this sort (or indeed most types of high-speed amplifier) is not straightforward since the load rectifiers of the driver stage face into the control rectifiers of the power stage[1], and this prevents the proper circulation of magnetizing currents in the two amplifiers. A shunt resistance in the

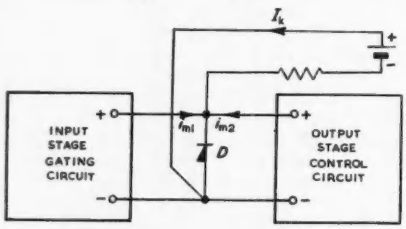


Fig. 9. Interstage coupling circuit

coupling is a possible way out of the difficulty, but is wasteful and reduces power gain. The problem may be satisfactorily solved by means of using a " constant current " coupling device. In its elementary form this consists of a rectifier supplied with current from a high impedance source : the general principle of operation may be outlined by reference to Fig. 9. Here the constant current I_K is adjusted through the diode D to a value that just corresponds to the sum of the maximum magnetizing currents of the two stages. Assuming for the moment that no reactors in the system fire in the gating periods, the magnetizing currents of the two amplifiers flow into the diode " reverse-on " without interaction. If now the driver reactors fire, the coupling diode becomes blocked, and the flow of magnetizing current in the power stage is stopped. This prevents any further change of flux level in the power stage for the rest of the half-cycle. It follows then, that the firing instant of the pre-amplifier during gating determines the flux level set in the power stage during sampling, hence the necessary coupling conditions are satisfied. If a coupling of he sort described is employed in an arrangement where the power stage feeds the armature of a D.C. motor, the scheme outlined breaks down and a considerable time lag is introduced into the system. This is because of the blocking action of the motor back E.M.F.

The mechanism involved becomes more complicated to follow when dealing with a three-phase system hence the half-wave model shown in Fig. 10 will be used for the purposes of explanation.

The mode of action is shown in Fig. 11 and treats the case where a step input is applied to the first stage demanding a reduction of motor speed from maximum to ½ maximum. The operation is shown in five epochs :

- A Steady state—motor at maximum speed.
- B Transient—step signal input, motor back E.M.F. not appreciably changed.
- C Transient—motor speed and back E.M.F. falling.
- D Transient—motor runs underspeed.
- E Steady state—motor at half maximum speed.

These divisions in time are somewhat artificial but assist in clarifying the operation.

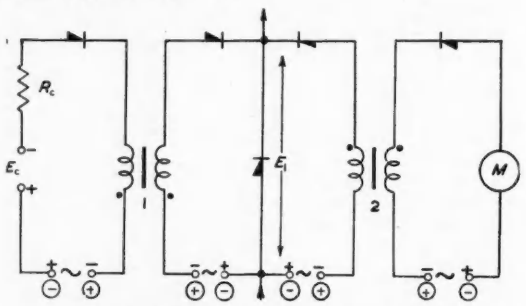


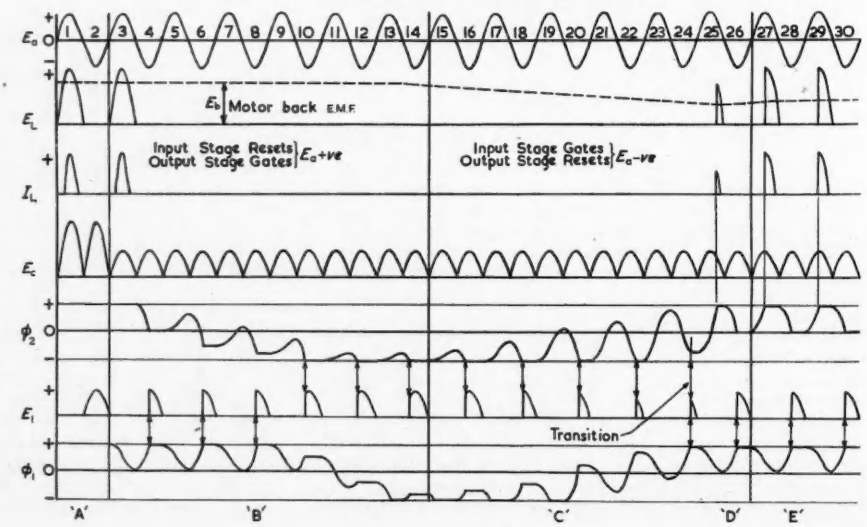
Fig. 10. Single-phase, half-wave model of coupled amplifier

In the first period A, the system is in steady state and no flux changes occur at all in the cores since both stages are delivering maximum voltage.

In period B the flux in core 2 is re-set in the normal manner during ½ wave No. 4 ; in the following gating period the flux in core 2 is not swept up to positive saturation because the voltage-time integral applied to the core is less than that applied during sampling and is given by $\int_0^{\pi} E_{\perp} dt. - E_{\perp}/2f.$

From here until ½ wave No. 10, the flux in core 2 is " spiralled " down to negative saturation, where an important change of circuit operation takes place, i.e. the *power* stage blocks the coupling diode and freezes the flux level in the driver stage.

Fig. 11. Construction showing mechanism of " flux depression "



This condition repeats for successive cycles until the flux in the first stage is also sent to negative saturation. If the control circuit impedance of the first stage is low, large circulating currents result.

In period C it is assumed that the motor back E.M.F. is falling, consequently the voltage-time integral applied to core 2 increases during each successive gating period. The fluxes in both cores, therefore, approach progressively nearer to positive saturation and the power stage gradually relinquishes control of the coupling diode. At the end of the period, core 1 fires before core 2 can reach negative saturation so it abruptly seizes control of the coupling means. The actual transition is shown in ½-wave No. 24.

Period D shows a transition phase with the motor under-speed and the current pulses to the armature just breaking through. This period merges into the final phase with the system in steady state at half output and the appropriate changes of flux taking place in the two cores.

The phenomenon described may be termed "flux depression" and unless counter-measures are taken, all the advantages of a high-speed amplifier drive are lost. The means adopted for overcoming this difficulty are set out later and are shown for a two-stage three-phase amplifier; the broad principles, however, are generally applicable.

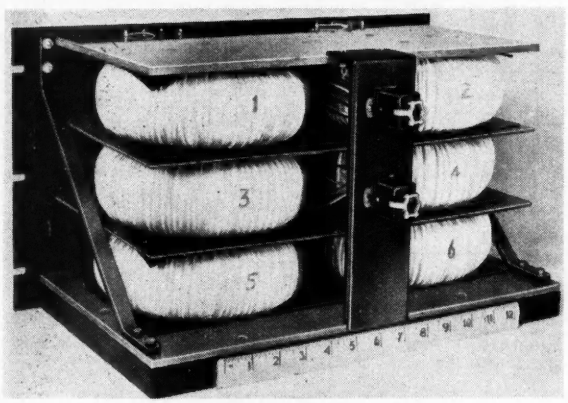


Fig. 12. Basic transductor assembly

Experimental Amplifiers

In order to check experimentally the validity of the various three-phase arrangements, and also to establish the form of the control voltage/current characteristics, a set of reactors working at 400c/s and handling an output power of about 10 watts were used. These early experiments confirmed that the circuits were basically sound. They also demonstrated the rather surprising fact that the magnitude and form of the I_c/E_c characteristics of all the configurations tested, including the single-phase full-wave circuit were substantially the same. However, in order to obtain a better evaluation of the three-phase high-speed magnetic amplifier it was decided to design a 50c/s multi-stage unit handling an output power of about 1kW and used for feeding the armature of a separately excited D.C. motor rated at ¾ h.p. The motor itself is embodied into a speed control system for driving a small 1 600c/s generator or alternatively for swinging the beam of a component test centrifuge. In the first case a constant speed is required, and in the second, a speed range of 20 : 1 is needed. Both schemes involve the use of three-stage amplifiers, the power output and driver stages being three-phase full-wave units in each case. The first stage for the alternator application is a conventional magnetic amplifier working at 1 600c/s and for the centrifuge the pre-amplifier is electronic, operating directly from three-phase rectifiers without smoothing. Of the two control systems, the centrifuge application is the more advanced at the present time being in the final stages of detailed engineering; for this reason the following sections will be concerned with this particular application only.

Practical Application of the Three-Phase Magnetic Amplifier

Power and Driver Stages

The power stage reactors employ Permalloy "F" spiral tape cores 6½in O.D., 5in I.D. and 1½in axial length, and were specially made by S.T. & C. Ltd. The core boxes were made by winding glass fabric tape impregnated with a thermo-setting polyester resin around a split ring and parting the case off, inside and out, in a lathe after the resin had set. The wall thickness is ½in and the finished item was found to be very strong. Each core, after boxing was hand wound with 2 000 turns of 18 S.W.G. wire for the load coils and 90 turns of 16 S.W.G. for the control. Six units, for direct connexion to the three-phase 440V main were then mounted on a modified 19in panel to form the basic transductor assembly shown in Fig. 12. The load rectifiers comprise six pairs of Westinghouse type 13C35 units enclosed in a small oil-cooled tank 3½in deep and mounted adjacent to the transductor unit. The voltage transfer characteristic was found to be exceedingly linear, no discrepancies being observable when employing normal laboratory multi-range meters.

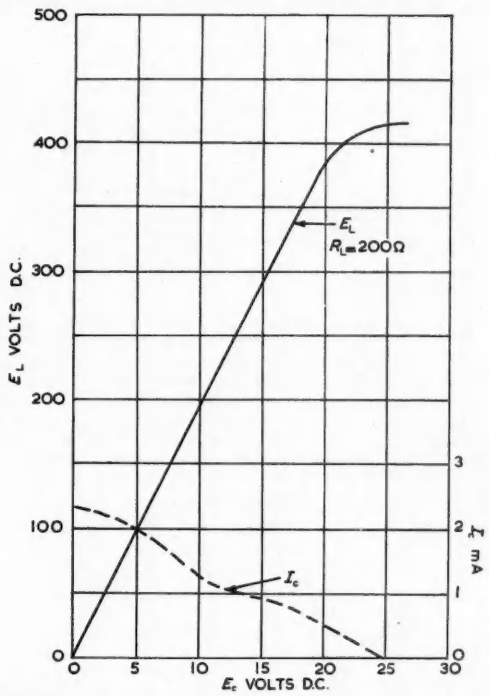


Fig. 13. Transfer characteristic of driver and power stages in cascade

The driver stage employs ⅜in stacks of 1½in square H.C.R. laminations and employs B.T.H. germanium junction rectifiers throughout. The turns ratio is 1¼ : 1, and the general construction follows normal transformer practice. This amplifier, together with the remainder of the circuit, is housed on a separate panel below the other two. The transfer characteristic of the two amplifiers connected in cascade is shown in Fig. 13. From this it is evident that the power gain is 16 000 (for a "one-cycle" response time), when a 200 ohm load resistor is connected to the output stage. With larger main rectifiers and an input stage based on the use of torroids instead of laminated reactors it is likely that a power gain in

the region of 40 000 could be secured. It was found that the transfer characteristic remained unchanged when supplying the armature of the motor running near maximum load conditions.

The Electronic Pre-amplifier Stage

The electronic pre-amplifier stage consists of a single 12AT7 valve executing the functions of triode pre-amplifier and cathode-follower drive to the first magnetic stage. The circuit follows normal practice, except perhaps, that the grid and cathode of the cathode-follower are clamped by means of biased rectifiers to restrict the range of control voltage. The rectifier MR_7 (Fig. 14) connected to the control circuit of the first magnetic stage is a control current limiter and prevents the flow of excessive currents during the brief cathode warm-up period. Incidentally, the transfer characteristic of Fig. 13 was obtained when using the cathode-follower drive.

possible. The modification ensures that blocking of the coupling means is possible in a " forward " direction only, e.g. going from driver to power stage, but not in the opposite direction. This is accomplished by splitting the single coupling path into two parts separated by an additional rectifier and each taken to a common high voltage supply through independent current limiting resistors. On the complete circuit diagram of Fig. 14, the elements involved are MR_4 and MR_5 and resistors R_2 and R_3. It is easily seen that if the driver reactors fire both rectifiers MR_4 and MR_5 become blocked, whereas if the power stage saturates in the negative direction MR_7 prevents MR_5 from being blocked, hence the driver gating magnetizing current is not interrupted. Once again rectifiers MR_4 and MR_5 are shown dotted since their function is carried out by the rectifier groups in the two amplifiers and consequently they are not needed.

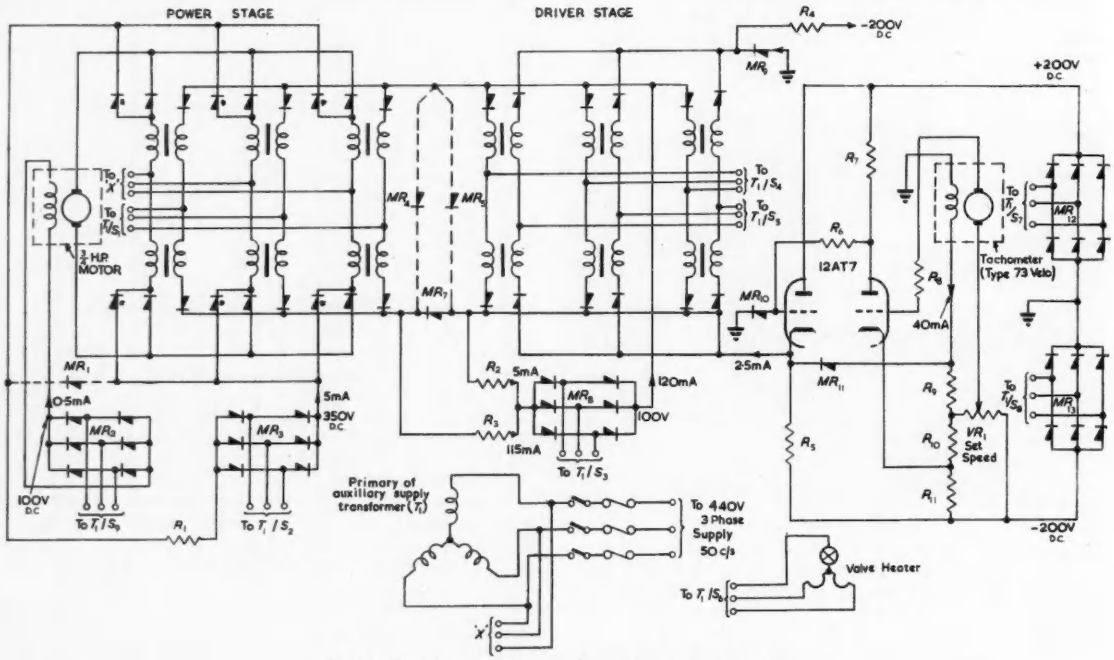


Fig. 14. Complete circuit diagram of magnetic motor control system

Anti-flux Depression and Coupling Circuits

From the considerations set out previously it is evident that if flux depression is to be avoided means must be found for permitting the proper flux changes to occur in the power stage, even when the motor back E.M.F. completely blocks the main rectifiers. In order to meet this requirement an independent low power load circuit is provided, which, feeding a non-active load is " open " during all gating periods. Since the only requirement of this auxiliary circuit is to pass the gating magnetizing current it is convenient to use a constant current source as a load element. This scheme is embodied into the circuit diagram of Fig. 14, where the rectifiers shown " starred " form the auxiliary load " routing " circuit and MR_1, R_1 and MR_3 constitute the constant current source and diode. The diode is shown dotted since in fact it need not be used at all because the routing rectifiers jointly perform the necessary function.

In addition to the scheme set out above, the interstage coupling is modified since it was found that under adverse supply conditions and when the load reactors were absorbing practically the entire applied voltage momentary blocking of the interstage coupling rectifier by the power stage was

Complete Motor Control System

As shown in the overall circuit diagram a type 73 Velodyne machine is used as a tachometer generator with its field supplied with current from the 200V D.C. line. A potentiometer connected in series with the field winding is used as a speed set control. Since the tacho output is a reasonably linear function of both speed and field excitation the arrangement is inherently self-compensating. The system is set up at the present time with a loop gain of 38db and is perfectly stable and fast in action. A detailed investigation into the dynamics of the whole system has not been attempted up to the present time but superficial tests indicate that the overall response is closely similar, if not identical to, an earlier motor control system employing a thyratron drive.

Conclusions

The work carried out to date in regard to multi-phase high-speed magnetic amplifiers must be regarded as being of an exploratory nature. Experience with the 1kW design, however, suggests that the special features of these amplifiers make them attractive propositions in some circumstances. At the present time a design study is under way, aimed at

producing a 10kW amplifier using cheaper core materials : it is hoped that this may replace a high power thyratron set in an industrial type motor drive. This unit would be entirely magnetic since the tachometer envisaged for use would supply sufficient high frequency power to operate the first stage of the system. At this juncture it may be stressed that the similarity between the core units described earlier and the

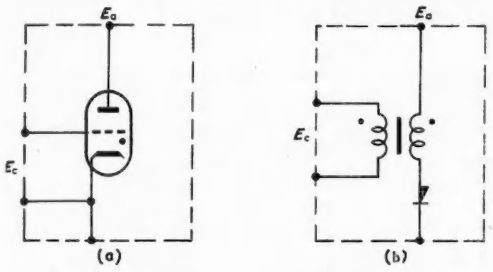


Fig. 15(a). Thyratron (b). Magnetic core unit.

thyratron valve is very striking since both are "on-off" devices and are substantially voltage controlled. The idea of ignition or firing angle, well known in thyratron practice is very readily applicable to the core units, and one may argue the equivalence of Fig. 15(a) and 15(b) with a certain amount of justification. Comparisons between magnetic amplifiers and electronic schemes have been made too frequently in the past to justify reiteration here, but at least it may be said that these new magnetic elements and ideas may well represent a challenge to a branch of engineering hitherto the exclusive field of thyratrons.

Acknowledgments

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A Junction Transistor Amplifier for Noise Cancelling Telephones*

A noise cancelling telephone is a device to enable a telephone conversation to take place under conditions of high ambient noise such as in an aircraft engine test department or hangar. The actual microphone is so arranged that, while it is sensitive to a nearby voice it cancels out the noise which enters both from the front and the back of the device. However, such microphones are inherently insensitive and require an audio frequency amplifier to raise their output to the level of a standard telephone output.

In addition, the input to the receiver requires amplification so that it can be heard above the high local noise conditions under which these telephones are intended to operate.

The ideal amplifier for such an application should be of very small size, use little power, and be capable of operation as soon as it is switched on.

The transistor amplifier will provide these conditions and the power consumption is so small that it may even be possible to operate the entire amplifier from the microphone energizing current normally supplied for the standard carbon microphone.

A possible circuit to give the power gain required is shown in Fig. 1.

This is a basic circuit that will work well, but is not necessarily the ultimate in design since, for example, it does not include D.C. working point stabilization in the output circuit.

Again to save space and weight the input and output are not critically matched, in fact a considerable amount of gain is lost, but in return the circuit is less dependent on transistor variations with time and from one to another.

The entire circuit shown above can easily be put inside half a matchbox and will fit behind the microphone in a standard telephone handset.

Thus thanks to the small size and power consumption of a junction transistor, all the advantages of a noise cancelling microphone can be obtained without adding to the size or external appearance of the telephone.

D.C. Stabilization of Junction Transistors

Unlike valves with their high H.T. voltage, the transistor circuit which will work with 3V H.T. has to be carefully designed to ensure that the collector current through the collector load resistance does not drop so much voltage that none is left across the transistor itself.

If for the first stage of an amplifier (grounded emitter) a collector current of 0·5mA is chosen, then the increase of the back leakage current with temperature will be such that when 35° or 45° is reached it will be comparable with the original

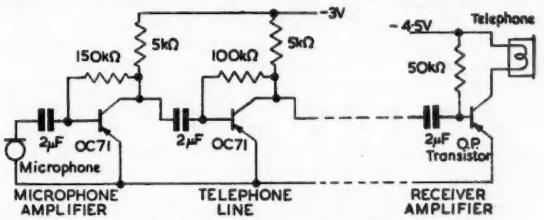

Fig. 1. Basic circuit for noise cancelling amplifier

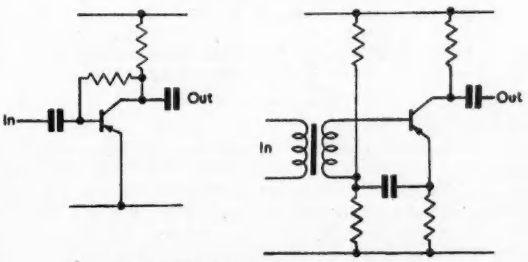

Fig. 2. Basic circuits for D.C. stabilization

collector current. This additional current through the collector load resistor will result in a reduction of voltage at the collector itself to almost zero and serious A.F. distortion will result.

Such a trouble can be overcome by providing the base current bias from a source that decreases as the back leakage current increases. This is, of course, D.C. negative feedback.

Two possible basic circuits are shown in Fig. 2.

* *Communication from Mullard Ltd.*

The Design of Triodes for U.H.F. Medium-Level Power Amplifiers

By W. E. Rowlands*, B.Sc., Ph.D., A.Inst.P.

A study is made of some of the factors involved in the design of U.H.F. triode output amplifier valves. A brief survey is made of considerations regarding the oxide-coated cathode and the design of the grid. An expression is derived for radiant heat dissipation in the grid which allows an estimate to be made of the effects of the heat reflexion coefficients of the electrodes.

Effects of evaporation from the cathode are investigated and relations between evaporation rate and grid growth are deduced. A procedure for estimating the effect of grid growth on valve constants and efficiency is indicated. Factors likely to cause an end of life of the valve are studied and a method is given of estimating the life as determined by grid growth.

The conflicting requirements of a valve of this type are outlined and it is shown that there is a value of cathode-grid spacing which gives an optimum power output at a given frequency.

An assessment of the possibilities at 2 000Mc/s shows that triodes are capable of a useful performance.

U.H.F. trunk radio systems require output amplifier valves of medium power level. Such valves should operate in broad-band systems, have a long life and reasonably high gain. For a valve working at 2 000Mc/s, a power output of 10W, a gain of about 10db, bandwidth of ±10Mc/s to 1db points, and a life of 10 000h are the sort of requirements in mind.

Triodes have some advantages for this application, in particular they make no great demands in the way of complex supply units and associated equipment such as magnets. On the other hand, their efficiency is limited by electron transit time effects. This means that very small inter-electrode spacings and fine-wire grids are necessary which make the valves difficult to manufacture. Furthermore, triodes tend to have rather a limited bandwidth.

A planar electrode system is usually chosen for a close-spaced triode meant to operate at about 2 000Mc/s. Compared with a cylindrical, or similar assembly, a planar grid is easier to construct and to maintain close to the cathode. Again, circular (disk) electrodes are normally used since these give rise to smaller stray capacitances. In such valves, the interelectrode spacings are much smaller than the lateral dimensions.

A relatively high electron emission density is required from the cathode and indirectly-heated oxide-coated cathodes have found almost universal application.

An attempt is made here to study some of the factors involved in the design of triodes for U.H.F. output amplifiers. No attempt is made to assess the relative merits of triodes and other valve types in this field.

The Cathode

An oxide-coating containing enough material to give a long life and applied by the normal spraying procedure has a thickness of the same order as the cathode-grid spacing. As the coating evaporates during life this spacing increases and the valve performance deteriorates. Thus, it is desirable that the coating be introduced as a thin, dense layer. One satisfactory method of doing this is to sinter fine tungsten powder on to the cathode base metal, spray the coating on this and crush it with a pressure of several ton/in^2.

Operating Temperature

The operating temperature depends on a number of factors. It is obviously essential that it should be high enough to maintain adequate emission. The actual value depends on the requirements of a particular valve and on the amount of positive ion bombardment, i.e. on the electrode potentials and the quality of the vacuum. On the other hand, it is desirable that the temperature be as low as possible to minimize the rate at which material is evaporated. Further, a low cathode temperature is of advantage in that it reduces radiant heat dissipation in the grid. With the type of cathode mentioned above, a temperature of about 720°C (oxide brightness) seems a suitable compromise.

When a desirable operating temperature has been determined, it is important that there should be little deviation from it. The electron emission and the evaporation rate are critically dependent on temperature so that small variations may be important.

The Evaporation Rate

The rate of evaporation of material from the coating is of prime importance in life considerations. Quite a number of factors are involved.

The evaporation rate probably depends on the cathode temperature, valve current density, base metal composition, the composition and treatment of the oxide-coating, the electrode potentials and the quality of the vacuum. In addition, at U.H.F. dielectric heating of the coating and bombardment by electrons returning to the cathode complicate matters.

Unfortunately there is little information on the dependence of evaporation on most of these factors. This makes it difficult to make estimates if the evaporation rate is involved and the designer is almost completely dependent on information gleaned from previous valves.

For a mixed (Ba, Sr oxides) coating on an "0" Nickel base, Woods[1] has measured the evaporation rate to be $2{\cdot}3 \times 10^{-6}$ g/cm^2/100h for a cathode temperature of 765°C (oxide brightness). He found that the rate was increased by 30 per cent when a current density of 20mA/cm^2 was drawn. The evaporated material was primarily metallic and there is some evidence[2] that it is mostly barium.

The Grid

The design and manufacture of grids for close spaced triodes has been described[3,4]. Molybdenum and tungsten wires are found to be the most suitable. For wire diameter less than 0·03mm tungsten is generally used. The wires are

* G.E.C. Research Laboratories, Wembley.

arranged to be in tension and it is found that grids of straight, parallel wires are preferable since the tensioning can be done in a reliable and reproducible manner.

The condition of the longest wire in the grid is the most critical, and attention will be directed on this.

If the heat dissipated from the grid by radiation is neglected and it is assumed that the dissipation is uniform along the wires then the temperature distribution along the wire is parabolic[4]. The maximum temperature at the centre of the wire is given by:

$$\theta_m - \theta_o = Ql^2/8k\pi r^2 \quad \ldots\ldots\ldots\ldots (1)$$

If the wire is stretched within its elastic limit, the strain which is just removed by a certain dissipation is:

$$\gamma = \alpha Ql^2/12k\pi r^2 \quad \ldots\ldots\ldots\ldots (2)$$

A nomogram representing these expressions for tungsten wires is shown in Fig. 1. This covers the range of parameters likely to be of interest and in its construction values of $k = 0{\cdot}4$cal/sec/cm/°C and $\alpha = 4{\cdot}4 \times 10^{-6}$/°C were used.

List of Symbols

C = valve output capacitance
d_P, d_N = grid wire diameter parallel and normal to cathode plane respectively
f = frequency in Mc/s
Δf = bandwidth in Mc/s
g_m = mutual conductance
I = intensity of heat radiation
I_a = anode current
I_Z = intensity of evaporation
i_a' = anode current swing
J = current density in A/cm²
J_o = energy conversion factor = 4·18W/cal/sec
k = thermal conductivity of grid wire in cal/sec/cm/°C
K_1, K_2, K_3 = constants
L_1 = valve life as determined by loss of emission
L_2 = valve life as determined by increase in μ
l = grid aperture diameter in cm
M_B = mass of barium in cathode in g/cm² of cathode area
P = grid dissipation due to electron bombardment in W/cm² of grid plane
P_o = power output
p = grid wire pitch in cm
Q = heat dissipation in grid wire in cal/sec/cm length of wire
Q_P, Q_R = contributions to Q due to electron bombardment and radiant heat respectively
R = load resistance
r = grid wire radius in cm
r_1 = grid wire radius corresponding to $\mu = \mu_1$, in cm
r_o, r_g, r_a = total heat reflexion coefficients of cathode, grid and anode
S_1, S_2, S_3 = cathode-grid, grid-anode and cathode-anode spacings in cm
$S_{1(opt)}$ = value of S_1 for optimum power output
V_g, V_a = grid and anode voltages
v_a' = anode voltage swing
W = radiation from cathode in W/cm²
Z = evaporation rate in g/cm²/100h
α = thermal expansion coefficient of grid wires
γ = strain in grid wire
η = efficiency
η_o = efficiency in absence of transit time limitations
θ_m = maximum wire temperature
θ_o = temperature of grid frame
μ = valve amplification factor
μ_1 = value of μ when the rated anode voltage only just draws the required anode current at zero grid voltage
ρ_g = density of material deposited on grid
ρ_e = "effective" density of evaporated material
S_1', d_P', etc. = rate of change of S_1, d_P, etc.

Some other symbols are used in the process of evaluating results, but their meaning is indicated where they occur.

Estimation of the Dissipation

The heat dissipated in the grid is derived from two main sources:

(a) radiation from the cathode and
(b) electron bombardment.

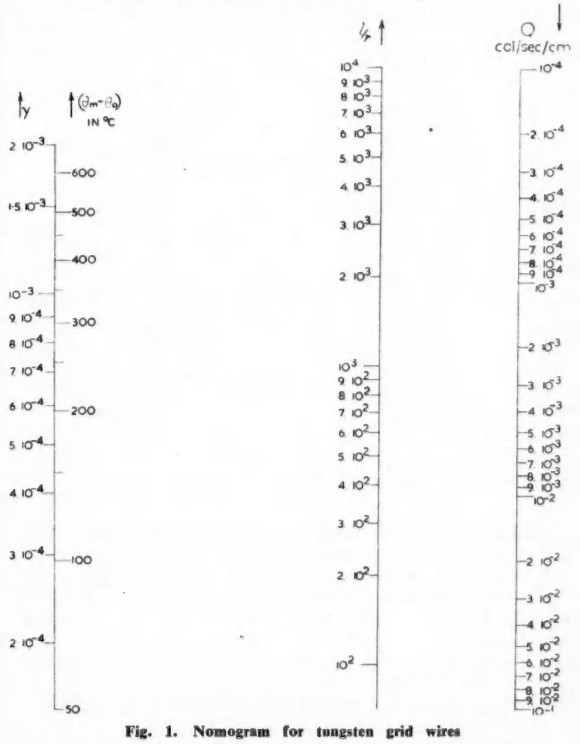

Fig. 1. Nomogram for tungsten grid wires

For a particular valve the contribution due to the latter can be fairly easily estimated and is given by

$$Q_P = Pp/J_o \quad \ldots\ldots\ldots\ldots (3)$$

Pohl[4] states that dissipation due to radiation from the cathode is usually less than 10 per cent of the total dissipation and that its contribution can be adequately represented by $2Wr/J_o$ (using our symbolism). For the type of valve under discussion, however, the radiant heat contribution is likely to be much higher than 10 per cent and a more detailed consideration is of value.

Radiant Heat Dissipation in the Grid

Consider first the radiation intercepted by a straight wire held parallel to a flat infinite radiator. The radiator 1, Fig. 2, radiates energy $W = \pi I$/unit area. The radiation from a small element of radiator area which is intercepted by a small length of wire, δl in Fig. 2, is

$$\delta q = I2r\delta l \cos\beta \cos\psi \, \delta x \delta y / z^2$$

Putting $\cos\psi = S_1/z$, $\cos\beta = \sqrt{(x^2+S_1^2)}/z$, $z^2 = x^2+y^2+S_1^2$

and integrating for x and y from $-\infty$ to $+\infty$ then the radiation intercepted by a small length of wire is $\pi Wr\delta l$.

Hence the radiation intercepted per unit length of grid wire is πWr.

Consider now the state of affairs in an actual valve. Radiation leaves the cathode and some is intercepted by the grid. Some of the remainder is reflected at the anode and some of this is again intercepted by the grid. Reflexion then occurs at the cathode, so that radiation is reflected to and fro between cathode and anode. Some is intercepted by the grid in each passage across the valve, some is lost at each reflexion and some is lost at the edge of the electrode space. Furthermore, of the radiation intercepted by the grid some is absorbed and the remainder is reflected to be intercepted by neighbouring wires or to rejoin the multi-reflexion process. A complete analysis of the situation would be extremely complex, but useful results can be obtained on making some approximations.

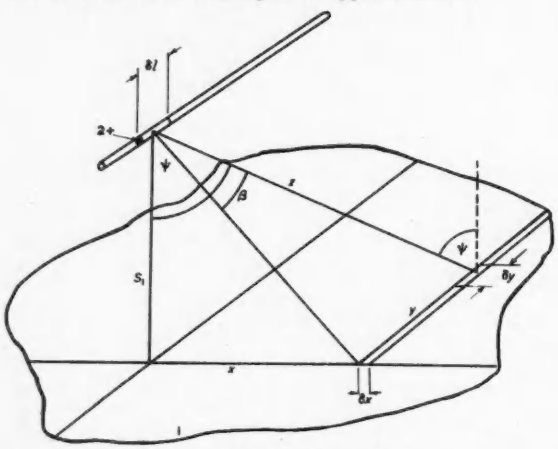

Fig. 2. Radiant heat interception

Neglect radiation originating at the grid and anode. Ignore the loss of radiation at the edge of the inter-electrode space and to counteract this also ignore the history of the radiation reflected at the grid. Further, suppose that the cathode can be treated as a simple reflecting surface.

The length of grid wire per unit area of grid plane is $1/p$. Radiant energy W/unit area leaves the cathode. An amount $\pi Wr/p$ is intercepted by the grid and the remainder, $W(1-\pi r/p)$ goes on to the anode. $Wr_a(1-\pi r/p)$ is reflected from the anode and of this $Wr_a(1-\pi r/p)\pi r/p$ *is* intercepted by the grid. The remainder, $Wr_a(1-\pi r/p)^2$, goes on to the cathode and so on.

Then the total radiation intercepted per unit area of grid plane is

$$\frac{\pi Wr}{p}[1+r_c r_a(1-\pi r/p)^2+..]+\frac{\pi Wrr_a}{p}[1+r_c r_a(1-\pi r/p)^2+..]$$

which reduces to $\dfrac{\pi Wr(1+r_a)}{p[1-r_c r_a(1-\pi r/p)^2]}$

since $r_c r_a(1-\pi r/p)^2 < 1$

Hence the dissipation per unit length of grid wire is:

$$Q_R \simeq \frac{\pi Wr\,(1-r_g)(1+r_a)}{J_o\,[1-r_c r_a(1-\pi r/p)^2]} \quad \ldots\ldots\ldots\ (4)$$

Taking reasonable values $r_c = r_g = r_a = 0{\cdot}7$ and $r/p = 0{\cdot}1$ then $Q_R \simeq 1{\cdot}8\ Wr/J_o$. This agrees quite well with the estimate of $2Wr/J_o$ obtained following Pohl's procedure, and this approach appears adequate for most purposes.

On the other hand, expression (4) enables the effect of variation in r_c, r_g and r_a to be estimated. As an example consider a change in anode reflexion coefficient, r_a. With $r_a = 0{\cdot}9$ and other values as before $Q_R = 2{\cdot}6\ Wr/J_o$, but if $r_a = 0{\cdot}15$ then $Q_R = 1{\cdot}1\ Wr/J_o$—a significant difference.

Limitation on Grid Design

An increase in grid temperature has two effects. First, primary electron emission from the grid increases and, secondly, thermal expansion of the grid wires tends to occur.

It is common practice to cover the grid wires with a layer of some other metal, such as gold, to reduce the grid emission level[5]. These valves are normally used with a bias resistor and the primary grid current flows through this. If the primary grid current becomes an appreciable part of the total biasing current, the operation of the valve may become unstable. An accumulative increase in valve current leading to eventual breakdown may occur. This state of affairs is not unlikely when the bias is produced by the grid current. However, if the total valve current is used for biasing (by using a cathode resistor) this tendency to breakdown is very much reduced. If a cathode resistor is used it is unlikely that the effects of primary grid emission will become a limiting factor in grid design before other considerations have set a limit.

The tendency of the grid wires to expand is overcome by having the wires in tension. From equations (1) and (2), $\theta_m - \theta_o = 3\gamma/2\alpha$ and taking $\alpha = 4{\cdot}4 \times 10^{-6}/°C$ and $\gamma = 3 \times 10^{-3}$ then the tension is relieved when $\theta_m - \theta_o \simeq 1\,000°C$. A value of strain of 3×10^{-3} is well within the capabilities of tungsten wire. However, recrystallization of the tungsten would lead to strain relief at this temperature. Recrystallization has been observed microscopically at 1 000°C and by X-ray methods at 800°C[6]. Further, there is no information on the creep of tungsten at elevated temperatures over long periods.

It would appear then that the maximum grid temperature should not exceed about 600°C for safe operation over prolonged periods.

Bandwidth

Valves of this type are generally used in coaxial-line common-grid circuits. Tuned input and output circuits are used, but the bandwidth is almost completely determined by the output circuit.

Morton and Ryder[7] show that there is a value of electron transit angle in the grid-anode region which optimizes the gain-bandwidth product. This value gives a high μ which is undesirable from life considerations. Normally grid-anode clearances giving a transit angle considerably less than the optimum are used.

It has also been shown[8] that best bandwidth results are realized when the active and stray capacitances are approximately equal.

Now the bandwidth $\Delta f \propto 1/CR$ ..... (5)

and for a given class of operation $R \propto e_a'/i_a'$ ..... (6)

For optimum power output the bandwidth of a triode in a circuit of this type is usually much less than is required in trunk radio work. A value of ±5Mc/s to 1db down points was found for a valve working at 2 000Mc/s. The required bandwidth can be realized by reducing R, but in so doing there is a loss of power output.

Effects of Cathode Evaporation on Valve Geometry

Some of the material evaporated from the cathode will be deposited on the grid and anode which are relatively cool. Since the grid-anode clearance is usually several times the cathode-grid clearance and the grid pitch, the change in valve geometry due to deposition on the anode can be neglected.

If the grid temperature is not excessive there will not be any appreciable migration or re-evaporation of the deposited material.

GRID GROWTH

The cross-section of the wire is modified as shown in Fig. 3.

Consider first the change in wire diameter parallel to the cathode plane. To estimate this, consider a plane perpendicular to the cathode plane and tangential to the wire, see Fig. 4. Suppose the cathode plane to be infinite and let the evaporation rate be uniform.

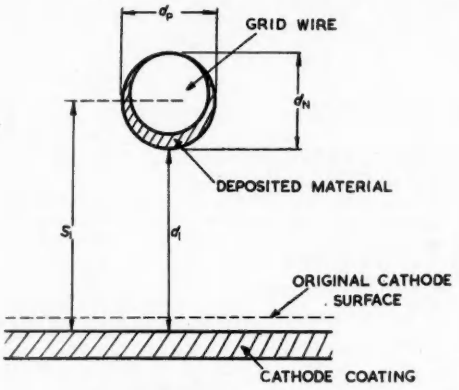

Fig. 3. Grid growth due to deposition

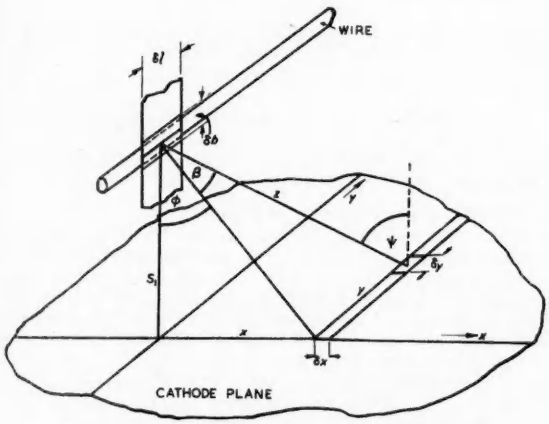

Fig. 4. Change in wire diameter parallel to cathode plane

In a high vacuum valve the cosine distribution law and the inverse square law apply to the evaporated material, hence $Z = \pi I_z$.

A rectangular strip, $\delta l \times \delta b$, on the tangential plane intercepts an amount of material, evaporated from an element of cathode area, given by

$$\delta F_p = I_z \delta l \delta b \sin\phi \cos\beta \, \delta x \delta y \cos\psi / z^2$$

Putting $z^2 = x^2 + y^2 + S_1^2$, $\cos\psi = S_1/z$, $\cos\beta = \sqrt{(x^2+S_1^2)}/z$, $\sin\phi = x/\sqrt{(x^2 + S_1^2)}$

and integrating for x from 0 to ∞ and y from $-\infty$ to $+\infty$

$$F_p = \tfrac{1}{2} Z \delta l \delta b$$

Hence the rate of increase of wire diameter, parallel to the cathode plane, is:

$$d_p' = Z/\rho_g \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (7)$$

Next, consider the change in wire diameter in a direction perpendicular to the cathode. Consider a plane parallel to the cathode and tangential to the wire on the side nearest the cathode (see Fig. 5). A strip $\delta l \times \delta b$ on this plane, as shown, intercepts material from an element of cathode area given by

$$\delta F_N = I_z \delta l \delta b \cos^2\psi \, u \delta u \delta\phi / z^2$$

Putting $u = d_1 \tan\psi$, $\delta u = d_1 \sec^2\psi \delta\psi$, $z = d_1 \sec\psi$ and integrating for ϕ from 0 to 2π and ψ from 0 to $\pi/2$ then

$$F_N = Z \delta l \delta b$$

There is no deposition on the point of the wire furthest from the cathode. Hence the rate of increase of wire diameter, normal to the cathode plane, is also

$$d_N' = Z/\rho_g \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (8)$$

EFFECTS ON μ, g_m AND ELECTRON TRANSIT TIME

The increase in wire diameter causes an increase in the μ of the valve. This effect can be estimated from equation (7) and a standard expression for μ or the chart given by Spangenberg[9].

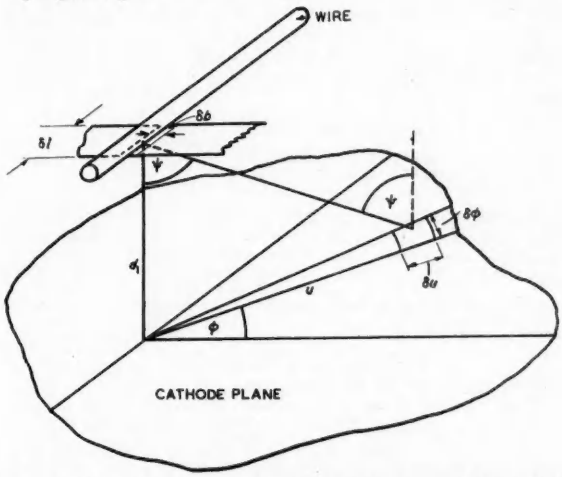

Fig. 5. Change in wire diameter in a direction perpendicular to the cathode

Growth of the grid tends to decrease the cathode-grid spacing S_1 at a rate of approximately $Z/2\rho_g$. Simultaneously the loss of material at the cathode increases S_1 at a rate of Z/ρ_e. Hence, there is a net rate of change of S_1 of

$$S_1' = Z(1/\rho_e - 1/2\rho_g) \quad \ldots\ldots\ldots\ldots \quad (9)$$

This change in S_1 affects the electron transit time in the cathode-grid region and may thus influence the efficiency of the valve. The change in efficiency may be estimated from Law's formula.

The change in S_1 and the change in μ cause the g_m to change. This can be estimated using a standard formula for g_m such as that given by Spangenberg[9].

Whether the loss of cathode material results in the coating shrinking by an amount corresponding to the density of the lost material or whether the coating is left with a more open structure is debatable. In any case, ρ_e can be assigned an "effective" value.

Life

Basically, the life of a valve of this type is governed by the evaporation from the cathode. This evaporation can cause the end of life in several ways.

LOSS OF EMISSION

The most obvious cause of end of life is loss of emission due to the complete loss of emissive material. In view of the evidence that there is a selective loss of barium the end of life is very near when all the barium is lost. As determined by this effect the life is

$$L_1 = 100 M_B / Z \quad \ldots\ldots\ldots\ldots\ldots \quad (10)$$

This life can be extended by using a replenisher type cathode[11,12] where a practically limitless amount of emissive material can be included. Unfortunately these cathodes operate at a higher temperature and this increases both the evaporation rate and the radiant heat dissipation in the grid.

ELECTRICAL BREAKDOWN

Contamination of the grid and anode reduces the electrical gap insulation between the electrodes. This increases the tendency to electrical breakdown which can destroy the valve. To our knowledge, there is no information allowing this tendency to be put on a quantitative basis.

CURRENT LIMITATION

The increase in μ, caused by grid growth, requires that the valve bias be reduced if the same valve current is to be maintained. No provision is usually made for positive bias. Thus, after the bias has been reduced to zero, to maintain the current, the valve output begins to drop. An "effective" end of life may be defined as occurring at this point of zero bias. After this there is a gradual deterioration in performance.

The current density can be expressed[13]

$$J = \frac{2{\cdot}335 \times 10^{-6}(V_g + V_a/\mu)^{3/2}}{S_1^2[1 + (S_2/S_1)^{4/3}/\mu]^{3/2}}$$

The effective end of life occurs when $V_g = 0$ and usually $(S_2/S_1)^{4/3}/\mu_1 \ll 1$ so that end of life occurs when μ is given by

$$\mu_1 = 1{\cdot}76 \times 10^{-4} V_a/S_1^{4/3}J^{2/3} \quad \ldots\ldots\ldots (11)$$

If r_1 is the grid wire radius corresponding to μ_1, the effective life is

$$L_2 = 100(r_1 - r)2\rho_g/Z \quad \ldots\ldots\ldots\ldots (12)$$

INTERELECTRODE SHORT-CIRCUITS

Grid growth causes increased heat dissipation in the grid. The radiant heat interception increases due to increased wire radius. Also, the grid must become progressively more positive because of increase in μ and this causes more electron bombardment.

Hence, a point may be reached when the maximum grid temperature exceeds the safe limit. Beyond this point a catastrophic end of life may occur due to relief of tension in the grid wires allowing an interelectrode short-circuit to develop.

This tendency should be allowed for in the design of the grid.

Valve Design Considerations

CONFLICTING DEMANDS

The requirements on a valve of this type are conflicting in several respects. Consider how variation of some of the valve parameters will affect matters.

Cathode-Grid Spacing

A decrease in this would increase the efficiency and the gain. It would also increase μ_1 (equation (11)) and hence the life L_2.

Grid Pitch and Wire Size

A reduction in cathode-grid spacing implies that the grid pitch must also be reduced to maintain adequate grid control. This means that either the life L_2 would be decreased due to an increase in initial μ value, or the grid-anode spacing has to be reduced causing an increase in C and a corresponding reduction in bandwidth, or the grid-wire diameter has to be reduced implying the use of a smaller grid aperture and thus tending to reduce the power output.

Grid-Anode Spacing

There is an optimum value of this for the best gain-bandwidth product. In practice grid-anode spacings considerably smaller than the optimum are used. Increasing the spacing would improve the gain-bandwidth product, but would decrease the life due to an increase in initial μ value.

Current Density

An increase in current density would increase the efficiency and the gain. These advantages could be used to increase the power output or to reduce the electrode area. The latter has the associated advantages of reducing C and allowing a finer wire grid to be used. On the other hand, there would be a reduction in life due to increased evaporation rate from the cathode and to a lower value of μ_1.

Anode Voltage

An increase in this would increase the power output, and also the life as determined by μ_1. However, there is a tendency to shorten the life due to cathode bombardment by higher energy gas ions.

It follows from this survey that the valve design must be a compromise between several conflicting demands. The information given in the preceding sections should be of aid in reaching such a compromise.

EXPRESSION FOR EFFICIENCY

Law[14] has shown that the efficiency of a triode can be represented by

$$\eta = \eta_0(1 - K_1 f S_1/\sqrt{V_a}) \quad \ldots\ldots\ldots\ldots (13)$$

and if f is in Mc/s, $K_1 = 0{\cdot}48$ for an amplifier. (This differs from the value of 1·2 given by Law since S_1 is measured in centimetres here as compared with inches in the original formula.)

Results on an experimental valve indicate that this expression gives estimates of efficiency appreciably too high for our purpose. This valve had values of $S_1 = 0{\cdot}1$mm, $V_A = 500$ volts and drive power of 2W/cm² of electrode area.

As expected, the efficiency followed a relation $\eta = \eta_0(1 - K_2 f)$. It fell from 20 per cent at 1 700Mc/s to 10 per cent at 2 300Mc/s. This gives a value of $\eta_0 = 50$ per cent and K_1 is estimated as 0·75.

OPTIMUM CATHODE-GRID CLEARANCE

When the cathode-grid clearance is reduced, the grid pitch must also be reduced. If adequate grid control is to be maintained, $p \leqslant 1{\cdot}5\ S_1$[15]. The grid wire radius must also be reduced if the screening factor is not to increase. Thus as the cathode-grid clearance is reduced the electrode area must also be reduced and this tends to reduce the power output from the valve.

On the other hand, a reduction in grid-cathode spacing increases the efficiency according to a relation $\eta = \eta_0(1 - K_2 S_1)$ where

$$K_2 = K_1 f/\sqrt{V_a} \quad \ldots\ldots\ldots\ldots (14)$$

Consider a valve where the anode voltage, current density, grid-anode spacing and drive power per unit area of grid plane are maintained constant. Let $p = aS_1$ and $r = bS_1$, where a and b are constants. Suppose that it is arranged that the grid operate at its maximum safe value. From equation (4), $Q_R \propto S_1$; and from equation (3), $Q_P \propto S_1$. Hence $Q \propto S_1$. To maintain the maximum grid temperature constant, $Ql^2/r^2 = \text{constant}$, i.e. $l^2 \propto S_1$.

Now the electrode area $\propto l^2$, so that the valve current $I_A \propto S_1$.

The power output $P_o = \eta V_a I_a$, hence $P_o \propto S_1(1 - K_2 S_1)$. This shows that there is a maximum power output for a value of S_1 given by

$$S_{1(\text{opt})} = 1/2K_2 \quad \ldots\ldots\ldots\ldots (15)$$

Furthermore $\Delta f \propto 1/CR$. If C is taken as the active grid-anode capacitance then $C \propto l^2$ approximately. Furthermore, since the μ is kept constant v_a' is approximately constant and $i_a' \propto l^2$. Roughly then, the bandwidth is independent of S_1.

Thus $S_{1(\text{opt})}$ gives the value of cathode-grid spacing

which gives an optimum power output-bandwidth product.

POSSIBILITIES AT 2 000Mc/s

An attempt is now made to make an assessment of the possibilities at 2 000Mc/s. Some of the estimates are very tentative due to the lack of information of some of the relevant parameters.

The following are thought to be reasonable estimates of some of the factors $V_a = 500V$, $J = 200mA/cm^2$, $W = 5W/cm^2$, $P = 0{\cdot}7W/cm^2$, $Z = 2 \times 10^{-5}g/cm^2/100h$, $\rho_g = 1g/cm^3$, and $M_B = 3 \times 10^{-3}g/cm^2$. The following relationships are typical: $p = 1{\cdot}5S_1$, $r = 0{\cdot}1p$, and $S_2 = 5S_1$.

K_1 is estimated as 0·75 from equation (14), $K_2 = 67$ and, from equation (15), $S_{1(opt)} = 0{\cdot}07mm$.

Then $p = 0{\cdot}10mm$ and $r = 0{\cdot}01mm$.

From equation (13), with $S_1 = 0{\cdot}07mm$ the efficiency at 2 000Mc/s is estimated as 25 per cent.

It would be a nice compromise to arrange that the grid temperature should reach its maximum safe value at about the same time that the effective end of life due to current limitation occurs. This latter point occurs when $\mu_1 = 190$, see equation (11), and from Spangenberg's chart[9] the grid wire radius is then $r_1 = 0{\cdot}02mm$.

Suppose at this stage that about one-third of the drive power is dissipated in the grid, then from equation (3) $Q_P \simeq 2 \times 10^{-3}cal/sec/cm$. Again $Q_R \simeq 2Wr/J_o$ so that $Q_R \simeq 5 \times 10^{-3}$. Hence $Q \simeq 7 \times 10^{-3}cal/sec/cm$.

It is required that $\theta_m = 600°C$ so that $\theta_m - \theta_o = 500°C$. From the nomogram, Fig. 1, this is so when $l/r = 8{\cdot}5 \times 10^2$ giving $l = 8{\cdot}5 \times 10^{-1}cm$. This gives the electrode area $\simeq 0{\cdot}57cm^2$ and valve current $\simeq 115mA$.

Hence anode input power $\simeq 57$ watts and power output $\simeq 14$ watts.

The life as determined by complete loss of emission is approximately 15 000h, from equation (10). Current limitation would set an "effective" end of life at about 10 000h, see equation (12).

Very approximately then a triode operating at 2 000Mc/s with an efficiency of 25 per cent, a power output of 14 watts, a gain of 11db and a life of 10 000h seems possible. The bandwidth of such a valve would almost certainly be inadequate and the power output and gain would have to be reduced to realize the desired bandwidth.

Conclusion

Triodes have a useful performance in trunk radio applications at 2 000Mc/s. An efficiency of 25 per cent, a power output of 9-10 watts at a bandwidth of ±10Mc/s, a gain of about 10db and a life of 10 000h, are about the best figures obtainable on the above argument.

A limited improvement on the above figures could probably be realized. The reflexion coefficients of the electrodes could be adjusted to reduce radiant heat grid dissipation. Also the limit on electrode area, set by grid temperature, could be extended by changing from a circular grid aperture. This would tend to increase the stray capacitances so that the advantage is somewhat doubtful.

A cathode capable of a higher current density at a reduced evaporation rate and reduced heat radiation, i.e. increased J/ZW factor, might enable a significant improvement to be made.

Acknowledgment

In conclusion, the author desires to tender his acknowledgment to the M.O. Valve Co. Ltd on whose behalf the work described in this article was carried out.

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A 15MeV Linear Accelerator

For Medical Use

A 15 million electron-volt linear accelerator designed and constructed by the Mullard Research Laboratories has recently been installed at St. Bartholomew's Hospital College. The machine is of the travelling-wave type, that is, it accelerates electrons continuously by subjecting them to a more or less constant electric field as they travel down the whole length of the machine. It is similar in many respects to the linear accelerator installed at A.E.R.E. Harwell in 1952,[1] but gives a somewhat higher energy and has its controls designed specifically for medical use.

Background

Travelling-wave linear accelerators produce electrons of high energy, which have a number of applications in pure and applied physics, industry and medicine. When these electrons are stopped by a target constructed of a heavy metal such as platinum, they produce hard X-rays and these find application in radiotherapy.

In conventional X-ray tubes the electrons are made to travel down an evacuated tube under the influence of a high voltage applied to the tube. The shortest wavelength (and hence their penetrating power) of the X-rays produced depends on the accelerating voltage. Thus electrons which have been accelerated by 1 million volts are said to have an energy of 1 million electron-volts (1MeV) and the X-radiation produced is described as 1MeV X-radiation.

In practice X-ray machines operating up to 250kV can be made fairly easily, and many such units are in use in hospitals. The problem of providing efficient insulation for higher voltages in X-ray tubes is, however, a difficult one and for operating voltages above about 2 million volts the size and cost of the equipment become prohibitive. Since X-rays of higher energies are valuable in the treatment of deep-seated tumours, there is a need for machines which produce high-energy electrons without the direct application of very high voltages.

One broad group of accelerators uses a magnetic field to constrain particles to move in a circular or spiral orbit. Machines in this class are the betatron and synchrotron for electrons, and the synchroton and cyclotron for heavy particles. Such machines usually give only a small beam current so that the X-ray output is not very great.

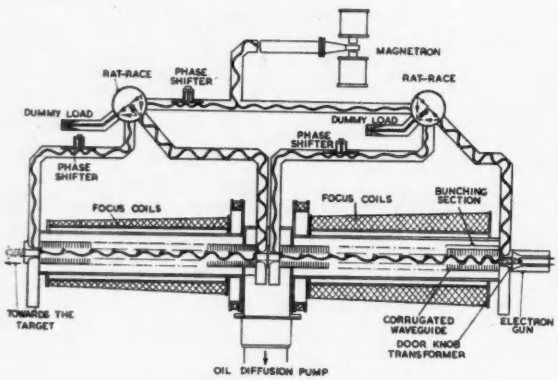
Methods of accelerating particles to high energies by means of comparatively low voltages were suggested by Wideroe in 1928 and by Professor E. T. S. Walton in 1929. These systems are known as standing-wave linear accelerators.

Radio-frequency voltages are applied at various points along a long evacuated tube. Particles come under the influence of the electric field produced by these voltages at times when the field is of such a polarity as to accelerate them.

Early linear accelerators were capable of accelerating heavy ions, but the acceleration of electrons to velocities approaching that of light was not feasible until high powers at microwave frequencies became available. This was provided by the cavity magnetron whose development was stimulated by wartime radar requirements.

This machine, like most present-day machines, is of the travelling-wave type. This means that instead of the particles receiving a large number of small accelerations, they are accelerated continuously in a more or less constant electric field down the whole length of the machine. The electric field is produced by passing the R.F. power down a type of circular waveguide known as a "corrugated waveguide". The electrons pass down the centre of this waveguide whose dimensions are arranged so that the electric field pattern travels at the same velocity as the electrons.

Like the 15MeV Harwell machine, the accelerator is divided into two halves, each taking half of the available magnetron power. The two halves receive the electron beam in series. Each half consists of 3 metres of corrugated guide.



Arrangement of the linear accelerator.

The energy provided by the first half of the machine is about 6·5MeV.

Since the accelerating field is still appreciable at the end of each 3-metre section, there will be considerable R.F. power still available at these points. This is used profitably by means of a recirculation system in each half, so that the input power to each section of corrugated waveguide is the sum of half the magnetron power and the unused power remaining after 3 metres.[2] The recirculation power is added to the generated power in a special form of "rat-race" waveguide ring circuit.

Electrons are injected into the first section of corrugated waveguide from an electron gun. This has pulses of about 50kV applied to it so that electrons with a velocity of 0·4*c* will pass into the waveguide where they form into close bunches. These bunches will travel in a part of the moving electric field such that electrons tending to lead the bunch will receive less acceleration while electrons tending to lag behind will receive more acceleration.

The R.F. field in the corrugated waveguide has a component which tends to produce defocusing of the electron beam. This defocusing is prevented by the application of a magnetic field by means of focus coils surrounding the vacuum envelope which contains the corrugated waveguide.

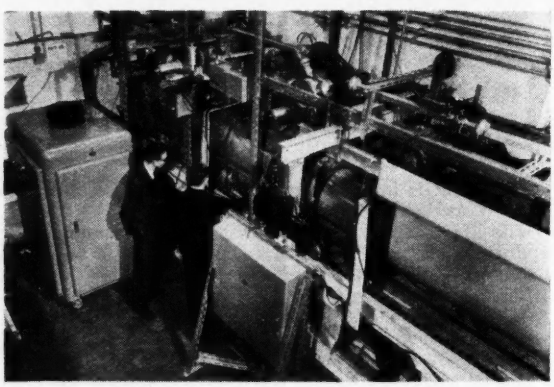
The closer the spacing of the corrugations the greater will be the power losses in the copper surfaces. On the other hand too few corrugations reduce the accelerating efficiency due to axial variations of the electric field.

At the input end of the corrugated waveguide the electron velocity is 0·4*c*, so that a guide wavelength of 4cm, which corresponds to a phase velocity of 0·4*c*, will keep wave and electrons in step. The corrugation pitch is here made 1cm, corresponding to 4 irises per wavelength. At the point in the waveguide where the electron velocity and therefore the guide wavelength, have doubled, the pitch is changed to 2cm between irises. This means that the attenuation of the corrugated waveguide due to losses in the walls is much less than if a uniform spacing had been adopted for the whole length. A quarter-wave transformer matches the wave impedances of the two pitches of waveguide.

As described by Bareford and Kelliher, the corrugated waveguide is made up of a large number of cells machined from copper pressings and soldered together using the copper-silver entectic. These cells were mostly machined to dimensions intended to give the R.F. wave a velocity equal to the predicted electron beam velocity. At four places, correcting sections were inserted to correct for any errors in wave velocity due to machining tolerances.

The 15MeV Harwell accelerator, like other machines constructed about the same time, gave electron energies somewhat less than the design figures indicated[1,3]. In the 15MeV St. Bartholomew's machine the corrugated waveguide in the second 3-metre section was redesigned to give a somewhat greater electric field in the axial direction. This resulted in the final electron energy being up to the original design figure.

The accelerator itself is divided into six units, each containing a one-metre length of corrugated waveguide, mounted on trolleys running on a system of rails. The electron gun section is also trolley-mounted. The miscellaneous supplies are divided into conveniently small units mounted in racks and



A general view of the linear accelerator.

connected by flexible cables fitted with plugs and sockets. Ease of servicing was constantly borne in mind during the design of the whole machine.

Use of the Machine

The machine is installed at the Physics Department of St. Bartholomew's Hospital College, where it will be operated under the direction of the Professor of Physics. The machine is being acquired by the hospital for the treatment of patients, but during the first few years it will be used entirely for research work in fundamental investigations into action of radiations on living tissue and into the best methods of treatment of malignant tumours.

St. Bartholomew's Hospital was the first to enter the field of high-voltage therapy by installing a 1 million volt X-ray machine in 1937. This machine is still in operation in the radio-therapy department of the hospital. The new linear accelerator is the largest and most powerful machine of its kind to be used for medical purposes anywhere in the world.

In addition to its use as a source of high-energy X-rays, the St. Bartholomew's accelerator is so designed as to make it possible to use the beam of 15MeV electrons directly for treatment. The therapeutic value of high-energy electrons has only recently been demonstrated, and has many advantages over high-energy X-rays in the treatment of certain types of tumour. A third use of the accelerator will be as a source of fast neutrons. The effect of these on living tissue has yet to be investigated. The neutrons are produced when electrons are made to hit a uranium target.

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A Torquemeter for Testing Gas Turbine Components

At 11 000rev/min 500kW

(Part 2)

By J. F. Field* and D. H. Towns*

A BLOCK diagram of the whole equipment is shown in Fig. 9 and a circuit diagram of the connexions of the photo-electric cells, differential amplifiers and other electronic equipment is shown in Fig. 10. These diagrams indicate that push-pull operation was adopted not only at the end from which two anti-phase voltages are required, but also at the other end. The two push-pull generators at end 1 of the torsion rod have been designated HF1A and HF1B and those at end 2 have been designated HF2A and FH2B. There are, in addition, the two generators which resolve the ambiguity of the quadrant being measured, i.e. they form the "hour hand of the clock". These generators have been designated LF1 and LF2 for ends 1 and 2 respectively.

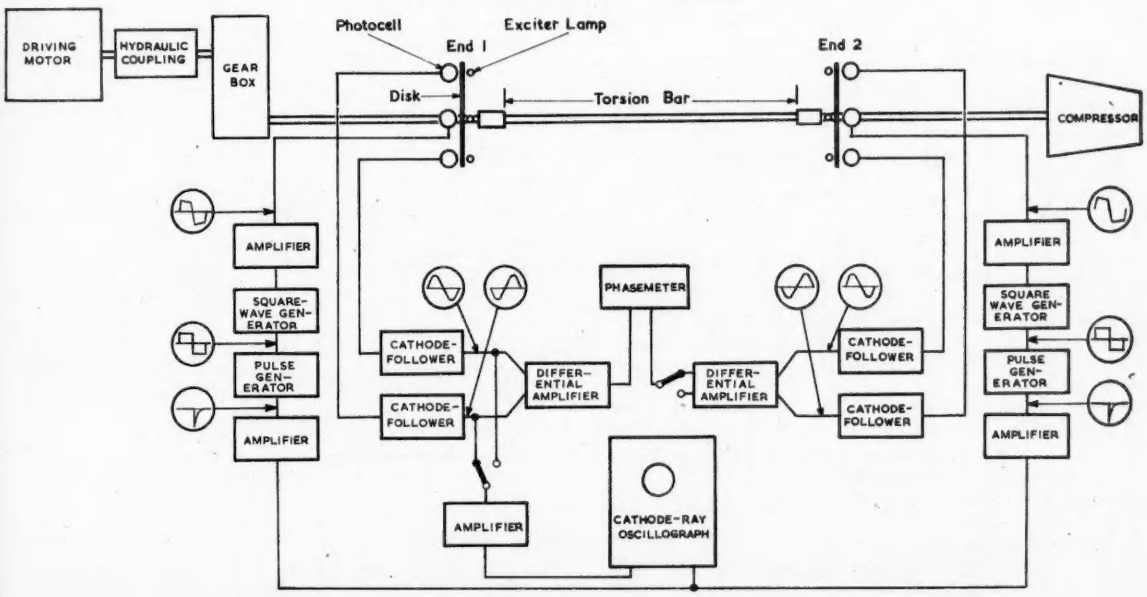
Photo-multiplier cells were used for the generators as these have the advantage of giving a large output and therefore do not require an amplifier. American 931A's were used, the British equivalent being Mazda type 27M1. The voltage dividing network is connected to the high-tension supply through resistor R_1 and is decoupled through capacitor C_1. The anode of the photo-electric cell is connected to the high-tension supply by its load resistor R_{12}, and the output is taken from the anode through a blocking capacitor C_3.

The phasemeter and associated apparatus were located at some distance from the voltage generators, which necessitated the outputs of the generators being delivered over a run of some 80ft of screened cable. In order to eliminate phase shifts due to the cable, its capacitance to earth was kept low by using 75 ohm coaxial cable. Even then it was found that the capacitance caused a variation in waveform with frequency; and to overcome the trouble the source impedance was reduced to about 250 ohms by interposing cathode-followers V_{3a} and V_{3b} between the photocell output terminals and the cables.

The outputs from the cathode-followers are then fed to their respective differential amplifiers. Each differential amplifier consists of a twin-triode V_5, having anode loads R_{37} and R_{38} and a common cathode load R_{34}. Bias for both triodes is obtained from R_{33}, which is decoupled by C_{11}. The voltage of the grid of each triode is held at the correct D.C. value relative to its cathode through resistors VR_8 and R_{32} and resistors VR_6 and R_{35} respectively, and the grids are decoupled from R_{34} and from each other by C_9 and C_{10}. The outputs from the two anode circuits are applied via blocking capacitors C_{12} and C_{13} to voltage dividers consisting of resistors R_{39} and R_{41} and resistors R_{40} and VR_7. With the component values shown in Fig. 10 the gain with anti-phase inputs is 3·53 and with in-phase inputs is 0·07, a ratio of 50·5:1. While a valve of higher mutual conductance, together with suitably selected anode and cathode loads, would undoubtedly have given a ratio of the two gains of 200 or more (see appendix), the value achieved with the 6SN7 valve was considered satisfactory and had the advantage of keeping the valve types standard throughout.

* South East Scotland Division, British Electricity Authority.

Fig. 9. Arrangement of the electronic equipment



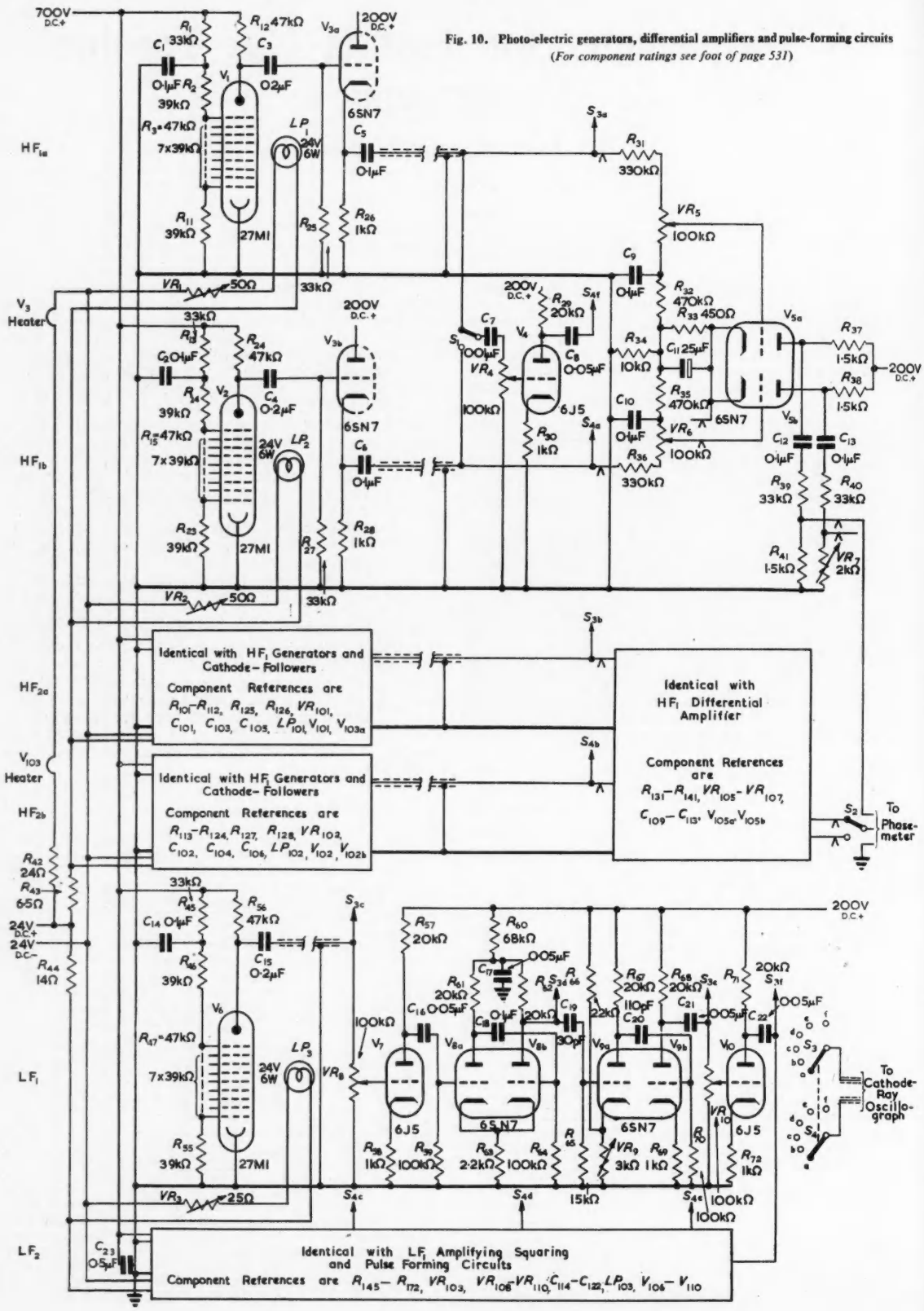
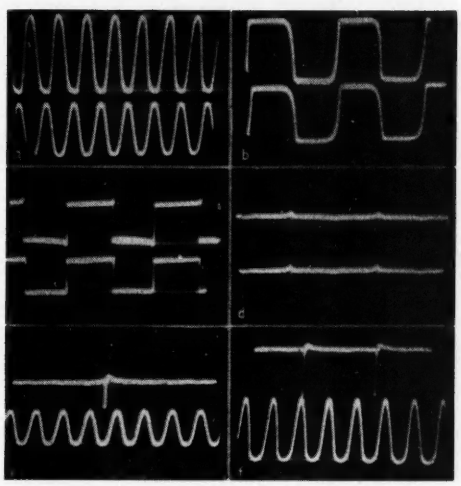


Fig. 10. Photo-electric generators, differential amplifiers and pulse-forming circuits
(For component ratings see foot of page 531)

The two L.F. generators, being associated with the twelve rectangular notches round the periphery of the disk, produce a voltage which has $1/10^{th}$ of the frequency of that produced by the H.F. generators and has an almost square waveform. There are no cathode-followers associated with the L.F. generators, partly on account of the lower frequency and partly because waveform distortion is not as important as in the case of the H.F. circuits. The output from each generator is first fed via a gain control VR_8 to an amplifier valve V_7. This is followed by a multivibrator, V_{8a} and V_{8b}, which is locked by the signal from V_7. The output of the multivibrator is taken from the anode of V_{8b} and consists of a signal having a waveform which is extremely steep sided and is, therefore, ideal for generating pulses. This signal is applied to a differentiating circuit consisting of C_{19} and R_{65} in series, which produces at the grid of triode V_{9a} a series of alternate positive and negative-going pulses. This triode is biased to cut-off point by means of R_{66} and VR_9, so that only negative-going pulses appear at its anode. These pulses are then amplified in V_{9b} and V_{10}, two stages of amplification being used in order to preserve the negative-going character of the pulses. It should be noted that the coupling capacitor C_{20} has a value which is sufficiently small to give appreciable attenuation of any mains ripple content introduced in the preceding stages. The pulses so derived from the L.F. generators at the two ends of the torsion rod are then combined and fed to one trace of a double-beam cathode-ray oscillograph. One of the two voltages from the H.F. generators at end 1 is fed to the other trace of the oscillograph by a buffer amplifier V_4. This amplifier can be selected through switch S_1 to either of the two inputs to the differential amplifier for end 1. The output of the buffer amplifier can be varied by means of gain control VR_4, which is connected to switch S_1 through C_7, the purpose of the latter capacitor being to prevent VR_4 being connected across C_9 or C_{10} and disturbing the D.C. conditions in the grid circuits of the differential amplifier. The display on the cathode-ray tube takes the form of one H.F. trace, about 5 cycles in length, to which the time-base is locked, and two L.F. pulses which are arranged to be coincident at zero twist. The L.F. pulse which is derived from the same end of the torsion rod as the H.F. trace appears as if locked to the H.F. trace, but the pulse derived from the other end of the torsion rod moves across the screen as the rod twists, and indicates on the H.F. trace the quadrant being measured. Since it will already be known from the position of the milliammeter reversing switch and the input phase-shifting switch whether the quadrant being measured is in the series 1^{st}, 5^{th}, 9^{th} . . ., 2^{nd}, 6^{th}, 10^{th} . . ., 3^{rd}, 7^{th}, 11^{th} . . ., or 4^{th}, 8^{th}, 12^{th} . . ., no great accuracy is required from the cathode-ray oscillograph display and the associated circuits in order to resolve the ambiguity relating to a particular series.

The photocell exciter lamps are supplied from a rectifier having a battery floated across its terminals. An A.C. source of supply for the lamps cannot be used as this would give rise to a ripple in the light intensity which would appear in the photo-cell output. The battery serves to smooth the rectifier output and absorbs variations in output due to sudden changes in the mains voltage. It consists of four 6V 150Ah commercial vehicle batteries which were on hand, although doubtless a battery of smaller capacity would have been equally effective. The lamps are connected to the rectifier and battery through two fixed voltage-dropping resistors, one for the four H.F. generator exciter lamps and the other for the two L.F. generator exciter lamps. In addition each lamp has an individual adjustable dropping-resistor which controls the intensity of the light on the cell. These adjustable resistors comprise the means for varying the photocell output and are also capable of controlling the waveform of the output to a certain extent.



(a) Outputs from pair of H.F. *generators at one end of torquemeter. (b) Outputs from the two* L.F. *generators. (c)* L.F. *generator outputs after squaring. (d) Pulses derived from square waveforms. (e) Normal display. Top trace shows* L.F. *pulses coincident, corresponding to zero torque. (f) Normal display. Top trace shows* L.F. *pulses separated by approximately* 900° *due to torque applied to torsion rod.*

The cathode-followers associated with the H.F. generators are located close to the photo-electric generators and the valve heaters were, therefore, connected in series and operated through a dropping-resistor from the same D.C. supply as is used for the exciter lamps in order to avoid the additional cabling which would be required for an A.C. supply to the heaters.

The double-beam oscillograph is connected through a six-position selector switch so that the waveforms at various points in the circuit can be examined while setting up the apparatus before a run is made, and can be checked during the course of a run. The following are the waveforms which can be displayed for the various switch positions:

Switch Position	*Waveform*
1	HF1A and HF1B generator outputs
2	HF2A and HF2B generator outputs
3	LF1 and LF2 generator outputs
4	LF1 and LF2 square waves
5	LF1 and LF2 pulses
6	Normal display.

COMPONENT RATINGS FOR FIG 10

RESISTOR TOLERANCES

R_{37} and R_{38} are a matched pair. Also R_{137} and R_{138}. All other resistors — ±20%

CAPACITOR WORKING VOLTS AND TOLERANCES

C_{11} and C_{111} 25V. C_{23} 1 000V. All other capacitors 350V. ±20%

RESISTOR RATINGS

½W	1W	2W	4W	7W
R_{29}	R_{34}	R_{44}	R_{43}	R_{42}
R_{57}	R_{134}	R_{66}		
R_{80}		R_{166}		
R_{87}				
R_{88}				
R_{157}				
R_{160}				
R_{187}				
R_{188}				

All other resistors—½W

VALVE TYPES

27M1 OR 931A	6SN7	½6SN7 OR 6J5
V_1	V_3	V_4
V_2	V_5	V_7
V_6	V_8	V_{10}
V_{101}	V_9	V_{107}
V_{102}	V_{103}	V_{110}
V_{106}	V_{105}	
	V_{108}	
	V_{109}	

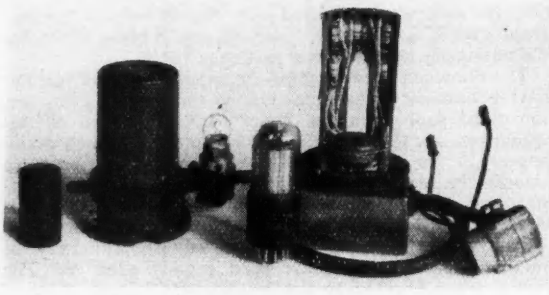


Photo-multiplier cell and lamphouse assembly

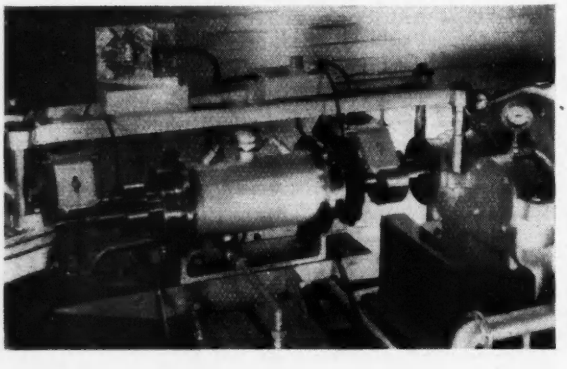
Various methods of mounting the photocells were tried out. Originally they were fixed directly to the adjacent portions of the compressor and gearbox, but the inevitable high frequency vibration at 11 000 rev/min, notwithstanding the good balance, caused the electrodes to disintegrate. This problem was resolved by mounting the whole photocell assembly upon a fairly heavy angle iron frame, which was supported from the main machinery by resilient rubber sleeve bushes. All the photocells were capable of adjustment in the peripheral and radial direction by means of fine thread jack screws with lock nuts. It was found most convenient to lock the lamphouses solidly on to the photocell housings.

The photo-electric cells were purchased complete in their housings together with the divider network R_2 to R_{11} (Fig. 10). Originally they were used as noise generators for jamming enemy radar, and as such embodied a small exciter lamp and its holder. Both the lamp and the holder were removed and a hole drilled in the housing opposite where the lamp filament had been, so that the cell could be excited from an external light source.

The cathode-follower units are shown in Fig. 10. It was necessary to mount these as closely as possible to the photocells in order that the capacitance of the cable carrying the signal from the photocell to the cathode-follower should be kept to a minimum. The photo-electric generators and the cathode-follower units were connected to a distribution box by means of plugs and sockets so that the whole of the beam carrying them could be readily removed at any time. In addition the box contains terminal blocks for cable connexion, the dropping-resistors for lamps and valve heaters, the lamp adjusting resistors, and capacitor C_{23} which it was found necessary to add in order to suppress mains hum picked up on the E.H.T. supply lead.

The photocells are very susceptible to changes in the E.H.T. voltage, appreciable variations in output taking place for comparatively small variations in voltage. It is therefore preferable that a stabilized power pack be used.

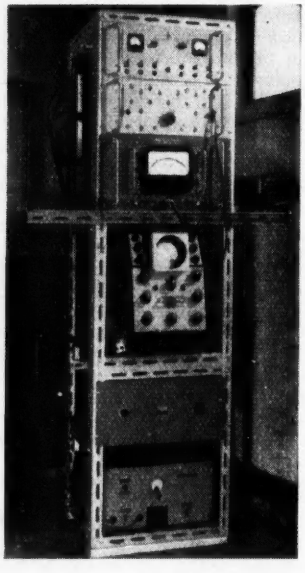
Torque meter assembly with cathode-follower unit



In the present instance an existing unstabilized power pack was employed in preference to buying or constructing a new one, and as a result it was found necessary to make periodic checks of the inputs to the differential amplifiers and, as necessary, to readjust them.

The first stage of setting the equipment to work is to ensure that the optical system is collimated, otherwise there will be loss of output and, in the case of the H.F. generators, distortion of waveform. The lampholders should be so positioned in the lamphouses that the lamp filament is presented edgewise to the photocell and the lamphouse itself should be turned so that the hole in it through which the light passes is directly opposite the hole in the photocell housing.

In the case of the L.F. generators nothing further is required, apart from positioning the disks on the shaft so that the light beams from both photocells are interrupted simultaneously. This will ensure that the L.F. marker pulses are superimposed one on the other at the zero-torque condition.



The torquemeter indicator panel

In the case of the H.F. generators it is necessary to check the H.F. voltage output for magnitude and waveform. This must be done with the torsion bar and its generator disks spinning so as to produce a voltage, but quite a low speed of rotation, say $1/10^{th}$ to $1/5^{th}$ full speed, is adequate for the purpose. The waveforms of the output voltages from each H.F. generator are then observed in turn. If any maladjustment exists, it is most likely to consist of misalignment of the holes in the lamphouse and photocell housing in relation to the holes in the disk. The flexible mounting of the photocell beam provides a ready means of checking such misalignment, since by pushing or pulling on the brackets carrying the photocells and lamphouses it is possible to move them inwards or outwards radially. If either pushing or pulling causes a reduction in output together with a deterioration of waveform, then the photocell is in the optimum position. If on the other hand the output increases and the waveform improves when the bracket is either pushed or pulled, an indication will be given of the direction in which the photocell should be moved in order to obtain the optimum position, the necessary adjustment being made by means of the screwed rods from which the photocell brackets are suspended.

At the same time as the foregoing adjustments are being made, the variable dropping-resistors for the exciter lamps should be set. In the case of the L.F. generators the lamp brilliance need not be any greater than is required to give adequate signal strength and should not in any case be so great that the photocell anode current exceeds the maximum permissible, viz. 1mA. In the case of the H.F. generators, the aim is not only to obtain sufficient signal amplitude as in the case of the L.F. generators, but also to

achieve as far as possible an output voltage which has a symmetrical waveform.

It was found that the H.F. waveform exhibited a flat one one side corresponding to minimum light on the photocell. This was assumed to be due to a finite dark period when the light from the lamp was interrupted by the space between the holes in the disk and was countered by increasing the lamp brilliance sufficiently to cause a similar flat to appear on the other side of the waveform corresponding to maximum light on the photocell, this second flat being caused by overloading of the cathode-follower.

It may occasionally be found that one of the H.F. waveforms appears lop-sided. This can usually be corrected either by turning the lamp holder in the lamphouse or by turning the lamphouse itself. In some cases it may be necessary to make both these adjustments. If the condition still persists in spite of these adjustments being made, it may be due to a distorted lamp filament, in which case the lamp should be replaced. The output of the photo-electric generators should be in the region of 2 to 5 volts, which gives adequate signal-to-noise ratio at the input terminals of the equipment on the rack.

The next stage in setting up consists of adjusting the L.F. pulse-forming circuits, again with the torsion rod and disks spinning slowly. The mark-to-space ratio of the output waveform of V_{8b} is to a certain extent dependent on the amplitude of the signal at the grid of V_{8a}. VR_8 is therefore adjusted so that this mark-to-space ratio is about unity. VR_9 is then adjusted so that the cathode bias of V_{9a} is just sufficient to suppress completely pulses which are negative-going at the grid of the valve without at the same time effecting appreciable reduction in the amplitude of pulses which are positive-going at the grid of the valve. Finally, VR_{10} is set so that the pulse amplitude is about 10 volts at the anode of V_{10}.

If the disks have been positioned correctly on the shaft the pulses derived from the two ends should be coincident, but a small separation of the pulses can often be eliminated by altering the mark-to-space ratio of the output waveform of one or both multivibrators by means of VR_8 and VR_{108}. If, on the other hand, it is desired to eliminate a larger separation between the pulses, this can be done only by repositioning the disks on the shaft.

There now remains only the adjustment of the inputs to and outputs from the differential amplifier. The inputs to the amplifier require to be adjusted in respect of both phase and magnitude. Adjustment of magnitude is obtained through potentiometers VR_5 and VR_6. These are set so that the two inputs are equal and of such magnitude as to give approximately 70mV output. Adjustment of phase is done by shifting the photocells on their mounting brackets in a direction tangential to the disk, the aim being to arrange that the two inputs have a phase difference of 180°. The existence of 180° phase difference can be checked by connecting the phasemeter leads to the inputs of the differential amplifier through suitable voltage dividers. A simpler procedure is merely to display the input waveform on the cathode-ray oscillograph by turning the selector switch to the appropriate position, when the phase relationship between the waveforms can be observed. Since any minor departure from the anti-phase condition will be corrected by the amplifier itself, this method was found to be sufficiently accurate in practice, provided two further checks were applied. The first of these consists of examining the waveform of the voltage developed across R_{34} by means of a wander-lead from the oscillograph to the U-point connected to the cathodes of V_5, when any excessive departure from the anti-phase condition will be evident in the form of a fairly large voltage of fundamental frequency across R_{34}. Secondly, the torsion rod can be loaded so that milliammeter has full scale deflexion in the unshunted condition, corresponding to a phase displacement of either 90° or 270°. If S_2 is then operated, the milliammeter should have exactly full scale deflexion in the opposite sense if the amplifier outputs have a phase difference of 180°.

Finally, VR_7 should be set so that the outputs from the amplifiers are equal. If the phasemeter leads are now connected to the outputs from the differential amplifiers and the torsion rod is spun unloaded at low speed, a reading will be obtained on the phasemeter. This reading can be logged as the reading corresponding to zero torque or alternatively it can be reduced to zero either by means of the backing-off current or by a tangential repositioning of the H.F. photocells at one end relative to those at the other end. In doing the latter it will be necessary to check that the 180° phase displacement between the outputs of the photocells is preserved, although with the screw adjustment provided, this does not present any great difficulty if both screws are adjusted by the same amount when moving the cells.

Errors due to variation of the input voltage to the phasemeter must be avoided. The main causes of variation in the input voltage are changes in the E.H.T., H.T., and L.T. D.C. supplies and changes in frequency.

It has been found that the torsion rod used in this torquemeter has a very high degree of elastic stability and the instrument has maintained its calibration even after prolonged intervals between calibration tests, which, for the research work under discussion, had to be performed immediately after each test.

Acknowledgments

In conclusion, acknowledgment is made of the valuable assistance rendered by Messrs. R. L. Gudgeon, S. A. Soutter and S. M. G. Geercke, who together with the authors formed the small team responsible for the design and development of this instrument.

Appendix

Note on the Differential Amplifier Design

It can be shown that the gain of the differential amplifier is:

$$\frac{\mu R_a}{R_a + r_a} \text{ with anti-phase inputs}$$

and:

$$\frac{\mu R_a}{R_a + r_a + 2R_k(\mu + 1)} \text{ with in-phase inputs.}$$

where μ = valve amplification factor

r_a = valve impedance

R_a = anode load

R_k = cathode load

The in-phase inputs are, therefore, attenuated in relation to the anti-phase outputs by a factor:

$$\alpha = \frac{\mu R_a}{R_a + r_a} \times \frac{R_a + r_a + 2R_k(\mu + 1)}{\mu R_a}$$

$$= 1 + \frac{2R_k(\mu + 1)}{R_a + r_a}$$

In general, if α is to be large

$$\frac{R_k(\mu + 1)}{R_a + r_a} \text{ will be} \gg 1$$

and also μ will be $\gg 1$

so that an approximate expression for the attenuation is:

$$\alpha = \frac{2\mu R_k}{R_a + r_a}$$

$$= \frac{2g_m r_a R_k}{R_a + r_a}$$

where g_m = valve mutual conductance.

Again if a is to be large, the denominator $(R_a + r_a)$ should be small. In general, it will be possible to make R_a small compared with r_a, so that the expression for the attenuation further simplifies to:

$$a = 2g_mR_k$$

The amplifier gains are then:

g_mR_a for anti-phase inputs

$R_a/2R_k$ for in-phase inputs.

The design requirements of the amplifier can then be summarized as follows:

(1) For maximum relative attenuation, the mutual conductance of the valve and the cathode load should both be large.

(2) In order that the actual gain of the amplifier and the relative attenuation shall both be independent of the valve impedance, the latter should be large compared with the anode load.

(3) For maximum gain in the amplifier, the anode load should be as large as is consistent with it remaining small compared with the valve impedance as stipulated in (2) above.

A Coaxial Standing-Wave Indicator

For Frequencies near 10 000Mc/s

By F. A. Benson*, M.Eng., Ph.D., A.M.I.E.E., M.I.R.E., and G. V. G. Lusher*, B.Eng., Ph.D.

The design of a precision coaxial standing-wave indicator is described and some measurements with the instrument are discussed. Complete information is given for the construction of the instrument and attention is drawn to difficulties which are likely to be encountered during manufacture. The variations in the characteristics of silicon crystals suitable for use in the detector are also dealt with because they may easily lead to serious errors.

IN measuring the attenuation of coaxial cables at frequencies near 10 000Mc/s the authors first made a large number of measurements with a standing-wave indicator in a run of rectangular waveguide. It was found to be more convenient, however, to make such measurements in a system composed wholly of cables and coaxial lines. To do this it was necessary to produce a coaxial standing-wave indicator. Very little information can be found in the literature on such an instrument although the paper by Hirst and Hogg[1] and the book by Barlow and Cullen[2] are both extremely helpful. These authors are mainly concerned with indicators for rectangular waveguide propagating the normal H_{01} mode but many of their remarks apply equally well to indicators for either circular waveguide or air-filled coaxial line. Details are given in this article of an instrument which has proved to be reliable.

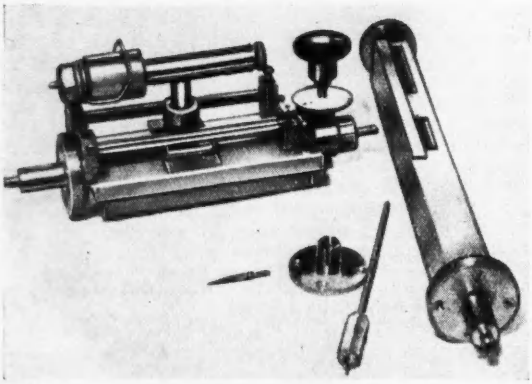


Fig. 1. Construction of the indicator

* *The University of Sheffield.*

The principles of its design are discussed and some tests on it are described. Care has been taken to describe fully the methods adopted for overcoming manufacturing difficulties which arise in producing an instrument of this type.

Repeated calibrations of the instrument with its crystal detector have shown clearly that there are pronounced changes in the characteristics of silicon crystals with time of operation which can lead to large errors if unnoticed. Some interesting facts are, therefore, included regarding the characteristics of these crystals.

Design Principles

The construction of the indicator which is shown in the photograph of Fig. 1, is best dealt with by considering three parts separately; first the coaxial line itself, secondly the probe and detector unit and finally the connexion to the external system.

The Coaxial Lane

The dimensions of the line are shown in Fig. 2. To ensure a constant impedance throughout the entire length of the line the diameter of the inner and outer conductors were machined to ± 0·0005in. The inner conductor was ground from stock silver-steel rod and the outer conductor was bored from square-section brass and finish reamed with a parallel reamer. The characteristic impedance of the line is near 70 ohms as most of the cables employed at frequencies near 10 000Mc/s, including those being tested, have a nominal impedance of this value (e.g. Uniradio 21, 32 and 43). The outside diameter of the line is the same as that of cable type Uniradio 21.

The design of the support for the centre conductor at the cable-sample end presents some difficulties and is rather important because the field pattern must not be disturbed at this point. A distrene spider (shown in Fig. 3) was used in which there is very little dielectric round the centre conductor where the field is strongest. The method of support at the other end is unimportant and a cylinder of distrene was employed as can be seen from Fig. 4.

The slot through which the probe projects is accurately

parallel to the common axis of the inner and outer part of the line.

It has been standard practice in the past to silver plate waveguide components of this type but measurements made by one of the authors[3] recently on electroplated waveguides have shown that plated surfaces are generally rougher than drawn ones. Plating may not give the improvements expected and it has not been used in the present case.

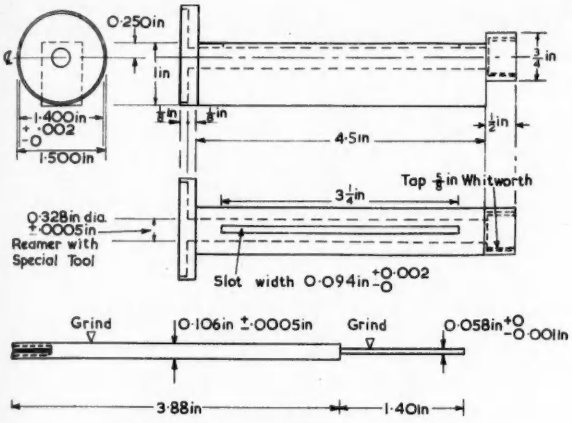


Fig. 2. Dimensions of the line and inner conductor

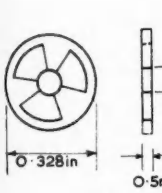


Fig. 3. Distrene spider

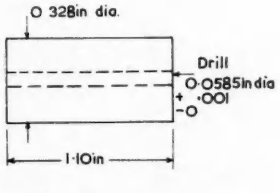


Fig. 4. Distrene cylinder

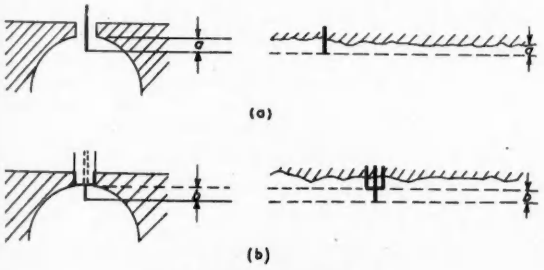


Fig. 5. Effect of shielded probe

The Probe and Detector Unit

A "shielded-probe" type of detector was used in which the "shield" takes the form of a tube round the probe and moves with it so that the effective length of the probe, i.e., the distance the probe projects beyond the shield, remains constant throughout the longitudinal movement of the probe carriage. This ensures that the amount of pick-up is independent of minor irregularities on the surface of the transmission line, as illustrated by Fig. 5. Fig. 5(a) shows an unshielded probe the distance *a* varying about a mean value depending on the inner surface of the line. As *a* is quite small, to avoid disturbing the field in the line, the variations in the amount of pick-up may be considerable. In Fig. 5(b), however, the distance *b*, which is the distance the probe projects beyond the shield, remains constant throughout the longitudinal movement of the probe carriage and the amount of pick-up is independent of any irregularities in the surface of the line.

Drawings of the probe carriage and its transit mechanism are shown in Figs. 6 and 7. The carriage has six degrees of freedom. By imposing five constraints on it there remains only freedom of motion parallel to the slot in the line. Figs. 6 and 7 also show how the constraints are

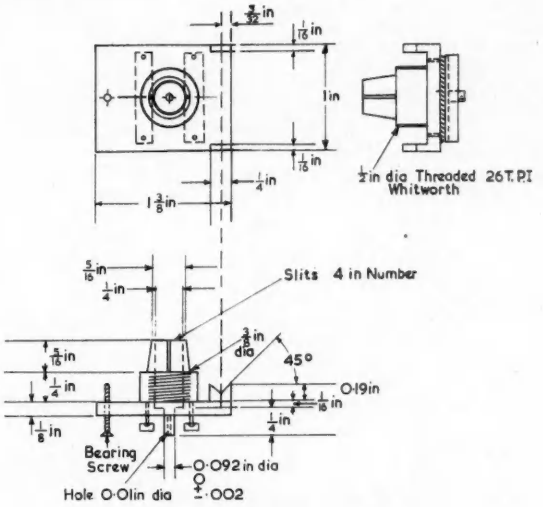


Fig. 6. Probe carriage and transit mechanism

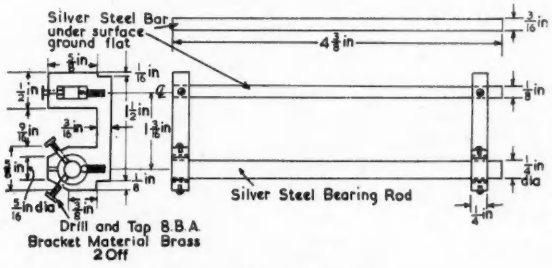


Fig. 7. Guide rods and brackets

imposed. Two bars of ground silver steel, one circular and the other rectangular, are mounted on the line and are adjusted to be parallel with its inside surface. The probe carriage has two V bearings which are forced into contact with the circular bar in two places, thus imposing four constraints and allow the carriage to move round the bar and parallel to it. The former motion is eliminated by the contact on the rectangular bar which has an accurately-finished bearing surface. When the axis of the circular bar and the bearing surface of the rectangular bar are parallel to the axis of the line the probe carriage will move so that the tip of the probe is always the same distance from the centre conductor. The carriage is kept in good mechanical and electrical contact with the bars by springs interposed between the carriage and the main contact shoes.

The main drive is by a thread of silk-nylon clamped at the centre of mass and friction of the probe carriage.

The resulting motion is smooth with negligible backlash; a metric vernier scale accurately determines the probe position.

The detector unit consists of a crystal fitted in a tuned concentric line as shown in Fig. 8. The output from the crystal is connected to a sensitive microammeter.

The Connexion to the External System

The method of supporting the inner conductor has already been described. If a cable of type Uniradio 21 (which has the same diameter as the line) is connected

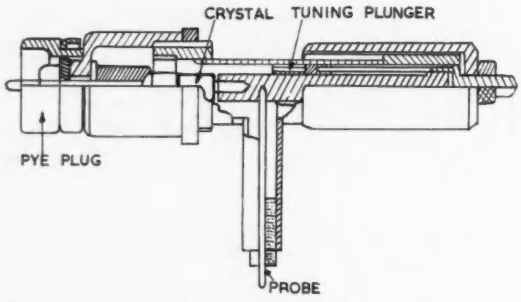


Fig. 8. Crystal detector

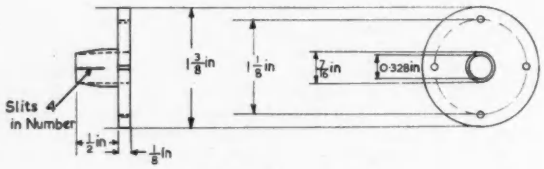


Fig. 9. Connector for cable Uniradio 21
(*Material—brass, silver plated*)

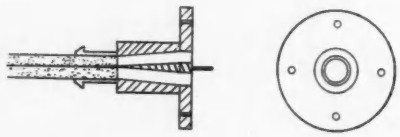


Fig. 10. Tapered connector for Uniradio 32 and 43

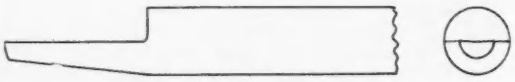


Fig. 11. D-bit
(*Silver steel ground to correct taper*)

directly to the standing-wave indicator there is a discontinuity due to the change of dielectric and of the inner-conductor diameter. This discontinuity is always present when using the indicator with polythene-filled cables. The type of connector used by the authors is shown in Fig. 9. The outer diameter is the same as cable type Uniradio 21 and the slotted hole in the centre conductor is an interference fit with the inner conductor of this cable. When smaller cables are used an air taper a half-wavelength long is fitted as shown in Fig. 10. The outer conductor of the coupling was machined with a tapered "D" bit, shown in Fig. 11, which was ground and hardened from silver steel. The inner conductors were machined from brass rod and drilled to take the respective cables, the final joint was a sweated soldered one.

Measurements with the Instrument

The instrument was first tested by short-circuiting the end of it and taking readings of the field pattern at frequent intervals along the line. In this way the effects of any eccentricity can be observed as differences in the maximum readings of the detector. The result of this

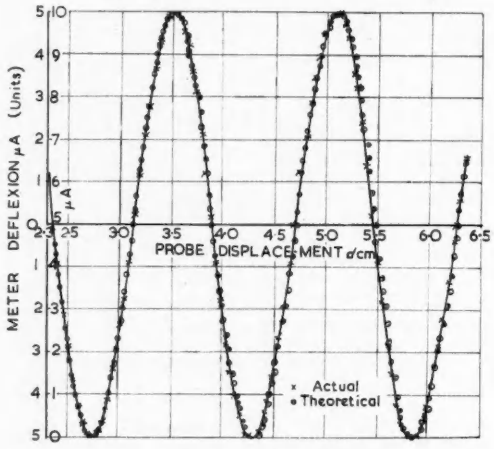


Fig. 12. Meter deflexion/probe displacement

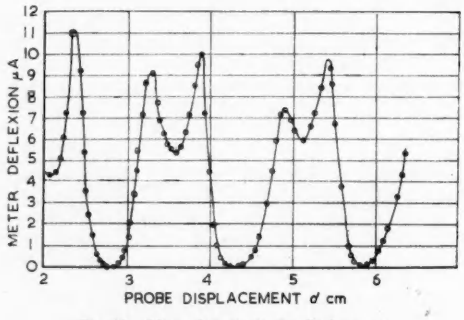


Fig. 13. Meter deflexion/probe displacement

test is illustrated by Fig. 12. It will be seen that the error is negligible. It should be noted that this error depends very much on the accuracy with which the distrene spider and cylinder are made. This test on the instrument also makes apparent any errors caused by a probe intrusion which is large enough to disturb the field. The probe can be regarded as an impedance in parallel with the line and will, therefore, have a different effect on the pick-up at different points on the line. If the probe impedance is purely resistive the only result will be a reduction in the amplitude of the maximum reading. If, however, as seems likely, the impedance of the probe has a reactive component the effect produced will depend on the sign of the line impedance at the point of probe intrusion. It follows that the error will not be symmetrical about a maximum or minimum value and in a really bad case the typical result of Fig. 13 can be obtained.

The instrument has been used with success to measure the attenuation of a number of coaxial cables. The block diagram of Fig. 14 shows the arrangement. The impedance presented by the test length of coaxial cable which is backed-off by the tuning piston are measured by the standing-wave indicator. For each position of the piston, three readings of the standing-wave indicator are taken at

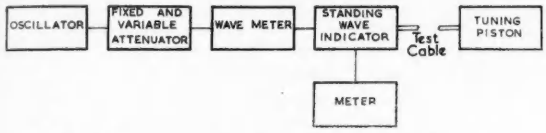


Fig. 14. Arrangement of equipment for cable attenuation tests

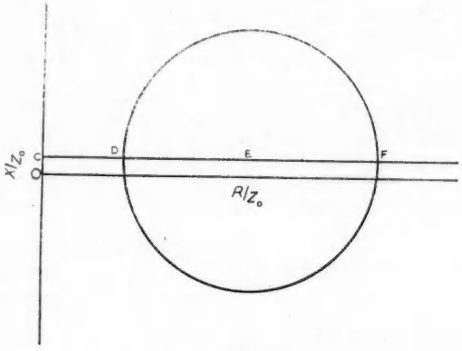


Fig. 15. Impedance circle
$al = 8.686 \tanh^{-1} \sqrt{(CD/CF)}$

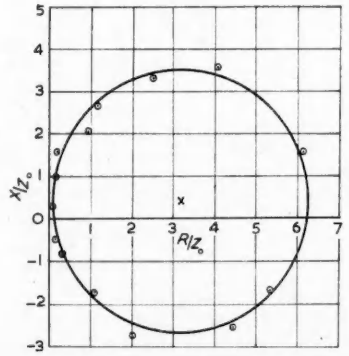


Fig. 16. Typical plot for 6 inch length of Uniradio 43

$al = 8.686 \tanh^{-1} \sqrt{(0.15/6.30)}$
$= 8.686 \times 0.1553$
$= 1.35$ db at room temperature

$\lambda_g/8$ intervals about a node position. If these are V_A, V_B, V_C, from the calibration curve, points on an impedance circle can be obtained by drawing arcs of radii V_A/V_C, and $\sqrt{2}V_B/V_C$ and centres 0, and -1 respectively. The attenuation al is given by $8{\cdot}686 \tanh^{-1} \sqrt{(CD/CF)}$ from Fig. 15.

Normally about 12 points are required for a circle, a typical result for a 6 inch length of cable type Uniradio 43 is shown in Fig. 16. The location of the points on this diagram confirm that the instrument described is quite reliable.

Crystal Calibration

The method of calibration uses the sinusoidal distribution of the field when the standing-wave indicator is closed by a short-circuiting disk. First a node is accurately located and λ_g is determined; then the carriage position is adjusted to give convenient meter deflexions. A series of meter readings and probe positions is noted and a calibration curve can then be plotted of meter reading against $\sin^2\theta$ where θ represents an electrical angle of $(360^\circ \times x/\lambda_g)$; x being the distance of the probe from the node. Repeated calibrations of the instrument with its crystal have shown that large changes occur in the characteristics of crystals during use but not during storage. Such variations may lead to considerable errors if allowed to pass unnoticed. A large number of unused crystals, both British and American, have been tested, some immediately on receipt from the manufacturer and others having been stored for

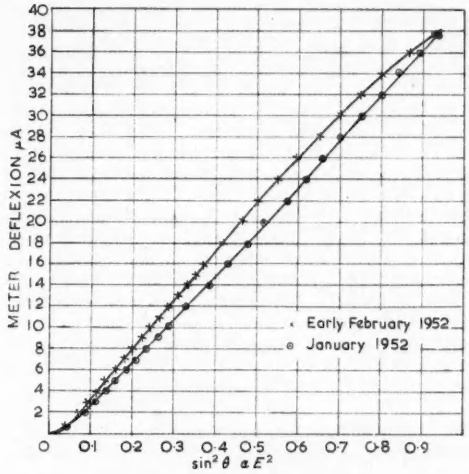


Fig. 17. Calibration of crystal detector
(*Sylvania type* CHS-IN21)

varying periods from 1 to 8 years in the laboratory. Crystals of a given type give almost precisely the same calibration curves. Variations in the characteristics of a particular crystal during use in a standing-wave indicator over a period of 1 month are shown by the typical curves of Fig. 17.

Acknowledgments

The authors wish to thank Mr. O. I. Butler for facilities afforded in the Laboratories of the Department of Electrical Engineering at the University of Sheffield. They are also grateful to Mr. J. Thomas, Manager of the Engineering Workshop, and to the late Mr. A. B. Rawlinson who constructed the instrument and made several helpful suggestions during its design.

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Electrical Breakdown in Waveguides at 3000Mc/s

By J. W. Sutherland*, M.A., A.M.I.E.E.

This article describes details of high power testing techniques in waveguides. Results on waveguides filled with gases other than air are given. The power at which breakdown takes place is related to gas pressure.

ONE of the serious problems in high power radio equipments operating at centimetric wavelengths is the electrical breakdown in the waveguide system.

The power handling capacity of an air-filled waveguide propagating the H_{01} mode is 416 kilowatts per square centimetre of the cross-sectional area of the waveguide, assuming a value of $2{\cdot}9 \times 10^6$ volts per metre as a breakdown figure for air at centimetre wavelengths[1]. Therefore, in size 10 waveguide, which has an internal section of 1·34in × 2·84in, the theoretical breakdown figure is 10·2 megawatts. If, however, there is any discontinuity in the rectangular section of the waveguide, then there will be local electric fields set up of greater magnitude than the uniform field. The power carrying capacity of the waveguide is therefore reduced by the presence of the discontinuity. The magnitude of the electric field set up by a local discontinuity is extremely difficult to calculate, but it can be shown that the electric field in the proximity of a spherical surface is inversely proportional to a function of the radius of the surface. It is therefore desirable in a high power system to avoid surfaces with small radii (i.e. sharp corners, edges, points, etc.), and all corners and bends should be "radiused", i.e. finished with as large a radius as possible. The object of the work reported here was to develop methods of testing high power waveguide elements and to investigate methods of improving their power handling capacity by filling with gases other than air.

Testing Techniques

A flexible test arrangement was required for breakdown testing, and it was decided to build as simple and robust a modulator as possible. The result, which was designed to give maximum peak power for minimum size and circuit complication, was an A.C. resonant charging modulator operating directly from 50c/s mains, capable of giving modulator peak pulse power up to 6mW. The circuit is shown in outline in Fig. 1. A conventional blocking oscillator, synchronized to the mains frequency, was used to "fire" a circuit containing a trigatron. The output of the trigatron was applied to the igniter of the ignitron, which formed the main switch of the modulator, and discharged the artificial line through the pulse transformer. The modulator cubicle also incorporated a power unit to supply the electro-magnet for the magnetron.

The power output of the magnetron was measured with a direct reading thermistor bridge. The waveguide mount containing the bead thermistor was coupled to the main waveguide by a directional feed with a known coupling figure. A preset attenuator was also introduced into the side arm, to adjust the signal level at the thermistor. The thermistor bridge measured mean power, but since the duty cycle of the modulator was known quite accurately, the peak power could be deduced simply. The value of the preset attenuator was adjusted to make the bridge direct reading in peak power, in order to simplify the taking of readings. The bridge was of the type which is balanced with no incident power, and then rebalanced with the power entering the thermistor mount. The rebalancing is done by bleeding off some of the bridge current through a network containing a meter. The network is such that the meter reads directly in power[2].

The breakdown tests were carried out in a special

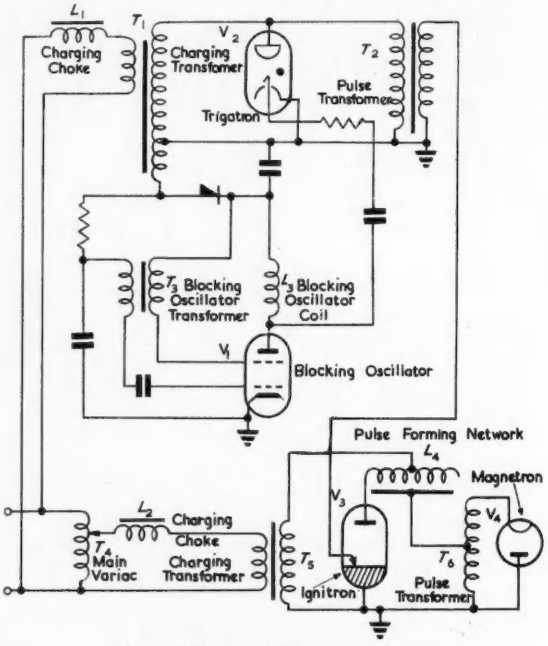


Fig. 1. Outline circuit of 50p/s test modulator

section of waveguide shown diagrammatically in Fig. 2. The section was designed to put a known gap across the waveguide and at the same time present the minimum mismatch. It consisted of a waveguide 8in long, in which the narrow dimension tapered from 1·34in at each end to ¼in in the middle. Each taper was half a wavelength long, and the ¼in gap was maintained for a distance of a quarter of a wavelength. Certain tests were also performed using a similar waveguide section with a ½in gap. To seal off the test section from the rest of the waveguide run for evacuation and gas filling purposes, 6in diameter disks of 0·020in thick mica were used in conjunction with a rubber sealing ring seated in a choke flange. An H-plane corner was introduced into the waveguide run, with a small hole drilled in the vertex of the corner, to facilitate visual inspection of the inside of the test section during breakdown. A diagram of a typical test arrangement is shown in Fig. 3, and the photograph shows the apparatus used for this investigation.

* *Formerly Metropolitan-Vickers Electrical Co. Ltd.*

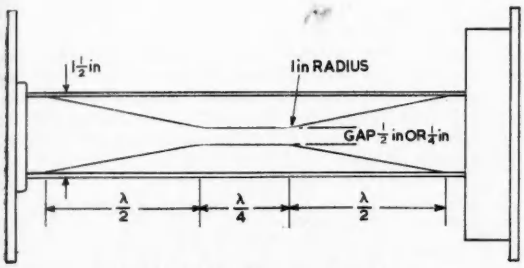


Fig. 2. Test piece for waveguide breakdown

It was important to assess the effect of pulse repetition frequency on the electrical breakdown since most radar equipments operate with a P.R.F. between 500 and 1 500p/s and the tests were to be carried out at 50p/s. A modulator was modified in such a way that the P.R.F. could be varied continuously from 50 to 750p/s. It was found that the initial "ticking" associated with the onset of the breakdown took place at a power level which was independent of P.R.F. However, the power at which a maintained discharge took place decreased very rapidly with increase of P.R.F. Therefore the tests with the 50p/s modulator were all related to the commencement of the "ticking" noise which indicated breakdown on occasional pulses.

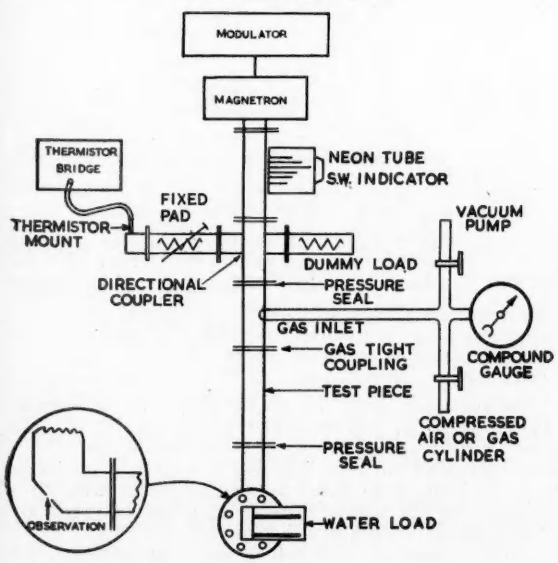
References 3 and 4 describe similar work in this field.

Tests with Air-filled Waveguide

Breakdown tests were carried out using the waveguide test section described above. The air pressure at which the breakdown started was measured for a series of power levels from the modulator. Each reading was repeated several times, and sufficient time was allowed between observations for the recombination of the ionized air. The results were remarkably consistent, and it was not considered necessary to initiate ionization by irradiation or other means. The air pressure was reduced by a small vacuum pump, and increased by a lead from the compressed air line. The manifold system included a compound pressure gauge.

The results are shown in Fig. 4. The full line shows the observed reading in each case, and the broken line is plotted by assuming that the power at which breakdown occurs is proportional to the square of the pressure, and extrapolating from one of the experimental points. The fairly close agreement between observed and calculated points indicates that Paschens law (gas pressure is inversely proportional to the voltage at which breakdown occurs) which was postulated for D.C. potentials, at least approximately holds good at centimetre wavelengths.

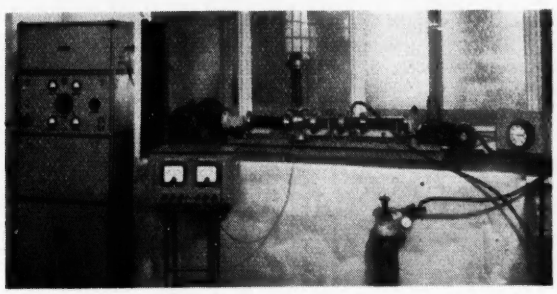
Fig. 3. Typical test arrangement



Tests with Other Gases

Sulphur hexafluoride and difluorodichloromethane (known as "Arcton 6") were used as gas fillings.

Sulphur hexafluoride is a colourless gas without odour or taste. It is completely inert, and in itself non-toxic. It may contain up to 100 parts per million of impurities as supplied commercially, and these may give rise to hydrogen fluoride on hydrolysis. It is, however, safe to use in conditions of reasonable ventilation. Its properties are described more fully in reference 5.



The equipment used for the breakdown tests

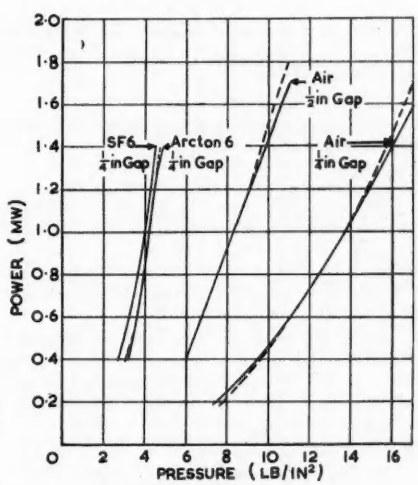


Fig. 4. Results of breakdown tests

"Arcton 6" is a colourless gas with a faint smell, it is totally inert and non-toxic and is not decomposed under normal conditions. Reference 6 gives more details of this compound.

Both are supplied in cylinders in liquid form. The relative cost of these gases is important when their suitability for incorporation into equipments is considered. The approximate cost (February, 1954) of sulphur hexafluoride is £3 to £4 per pound according to quantity, and of "Arcton 6," 4s. 6d. to 6s. 8d. per pound according to quantity.

To conduct the breakdown tests, the test section was totally evacuated, the gas admitted, re-evacuated, refilled and so on several times to ensure the purity of the gas. After each breakdown the section was evacuated and refilled. The results of the tests are recorded in Fig. 4.

It appears from these results that the relative power handling capacity of waveguides filled with air, "Arcton 6" and sulphur hexafluoride is approximately 1:9:10½.

There is no simple explanation of the nature of the discharge, and the mechanism of energy transfer between gas molecules at velocities approaching those corresponding to the ionization potential is so complex that it is incapable of treatment by simple mathematical reasoning (see reference 7).

In conclusion, it appears that "Arcton 6"—a cheap, non-toxic, freely available gas—can increase the power-handling capacity of a waveguide system by a factor of 8 or 9.

Acknowledgments

The author acknowledges the work of his colleagues, particularly in the design of the test modulator and thermistor bridge, and also the technical information provided by Imperial Chemical Industries Ltd. Acknowledgment is also made to Metropolitan-Vickers Electrical Co. Ltd., for permission to publish this article.

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R.F. Cable Characteristics Measured with a Q-Meter

By Jacob Shekel*

The conventional methods of measuring velocity of propagation, characteristic impedance and attenuation are discussed. A method is described of measuring the frequency of half-wave resonance on a Q-meter in such a way that the other parameters can be easily computed.

THE following three characteristics, which are of interest in specifying or testing cables for R.F. applications, will be discussed in this article:

1. Velocity of propagation.

2. Characteristic impedance Z_o, or its inverse, the characteristic admittance Y_o.

3. Attenuation.

There are a number of methods of measuring these characteristics, of which the following are those mostly in use:

1. Velocity of propagation is usually measured by finding the frequency at which a section of the cable exhibits resonance (half-wave or quarter-wave).

2. The capacitance per unit length is measured on a bridge, usually at an audio-frequency. This measurement and the velocity of propagation are sufficient to determine Z_o. An alternative method is to find a terminating impedance that will be transformed in a 1:1 ratio along a cable section of arbitrary length.

3. Attenuation is measured by substituting a calibrated variable attenuator for a section of the cable in a transmission system. The cable section has to be equipped with matched connectors at both ends.

In the method outlined in this article, the frequency of half-wave resonance of a section of the cable is measured on a Q-meter; but this same measurement is conducted in a way that yields enough information to compute the two other characteristics. The obvious advantages of this method are that a single measuring instrument is used, and all characteristics are determined from measurements executed at the same frequency (or, more precisely, in a small frequency range). The cable section is easy to prepare; it is open-circuited (i.e., cut off flush) at one end and any convenient and suitable connector, not necessarily a matched one, is mounted on the other end. It seems to the writer that the method is easily applicable to production testing, by setting limits on the quantities directly measurable on the Q-meter.

* *Scientific Department, Ministry of Defence, Israel.*

The Method

The cable to be tested has a characteristic admittance Y_o mhos (assumed real), and a propagation constant $\gamma = \alpha + j\beta$ (α in nepers/metre, β in radians/metre). The Q-meter is used to measure the input admittance of a section l metres long, whose end is open-circuited. This input admittance, in the general case, is:

$$\begin{aligned} Y &= Y_o \tanh \gamma l \\ &= Y_o \tanh (\alpha + j\beta) l \\ &= Y_o \frac{\tanh \alpha l + j \tan \beta l}{1 + j \tanh \alpha l \tan \beta l} \end{aligned}$$

Let G and B denote the real and imaginary parts, respectively, of Y, then:

$$G = Y_o \tanh \alpha l \frac{1 + \tan^2 \beta l}{1 + \tanh^2 \alpha l \tan^2 \beta l} \quad \ldots\ldots (1)$$

$$B = Y_o \tan \beta l \frac{1 - \tanh^2 \alpha l}{1 + \tanh^2 \alpha l \tan^2 \beta l} \quad \ldots\ldots (2)$$

At the frequency of half-wave resonance, f_o,

$$\pi = \beta l = 2\pi f_o l / v$$

where v is the velocity of propagation, in metres/second;

$$v = 2 f_o l \quad \ldots\ldots (3)$$

The input admittance at this frequency is real,

$$G = Y_o \tanh \alpha l \quad \ldots\ldots (4)$$

Another relation between Y_o and α is obtained from the off-resonance behaviour of B. Let $f = f_o + \delta f$,

$$\beta l = 2\pi / v \ (f_o + \delta f)\, l = \pi + 2\pi l / v \ \delta f$$

$$\begin{aligned} \tan \beta l &= \tan 2\pi l / v \ \delta f \\ &= \tan 2\pi l / 2 f_o l \ \delta f \\ &= \tan \pi \ \delta f / f_o \end{aligned}$$

If the deviation from the centre frequency f_o is small enough, the angle may be substituted for its tangent. The error of this approximation, as a function of the relative frequency deviation $\delta f / f_o$, is shown in Fig. 1. It should be borne in mind that neither the measurements made on a Q-meter, nor the usually required cable specifications, are of an accuracy greater than 1 per cent.

Another approximation will be made by writing 1 for

the denominator in equation (2). The validity of this approximation is dependent on cable attenuation as well as on the frequency deviation from resonance. Fig. 2 shows the attenuation of a half-wave section of three types of coaxial cables. (The attenuation of RG-21/U is intentionally achieved by a centre conductor of nichrome, so that this attenuation is already much higher than the values usually encountered in cables for regular R.F. applications). Fig. 3 shows the error of the approximation as a function of attenuation and frequency deviation, and it is evident that the approximation is valid even under the most extreme conditions that may be expected in practice.

Returning now to the off-frequency behaviour of B, and applying both approximations,

$$B = Y_0 (1 - \tanh^2 \alpha l)\, \pi\ \delta f / f_0.$$

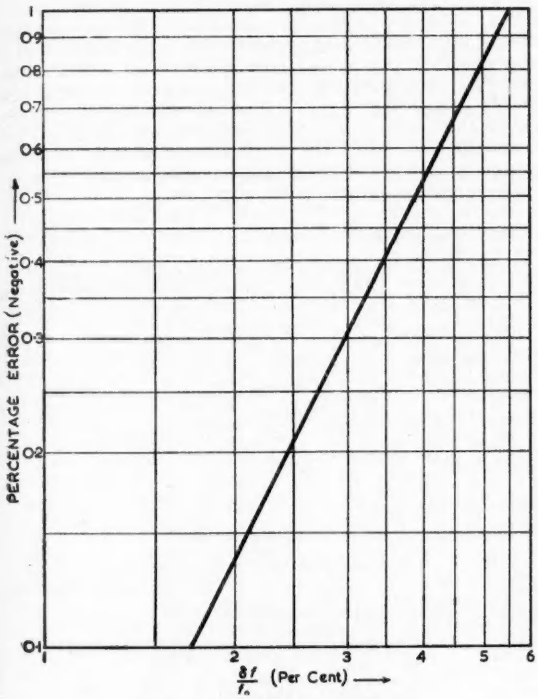


Fig. 1. Error of the approximation
$\tan \beta l \simeq \pi\ \delta f / f_0$

The Q-meter measures susceptance as an equivalent capacitance

$$C = B/2\pi f$$
$$= Y_0 (1 - \tanh^2 \alpha l)\ \delta f / 2 f f_0$$
$$C = Y_0 (1 - \tanh^2 \alpha l)\, \frac{f - f_0}{2 f f_0}$$

Equations (4) and (5) may be solved for Y_0 and α.

Measurement Procedure

A section, whose length corresponds (approximately) to half a wavelength at the test frequency, is cut off the cable to be tested. (The wavelength in cables with polyethylene dielectric is about 2/3 of that in air dielectric or free space propagation). One end of the section is cut off flush, and the other end is prepared for connexion to the capacitor terminals of the Q-meter. An auxiliary coil, that will resonate with about 40 to 80pF at the same frequency, is connected to the coil terminals.

Measurements are made at two frequencies, f_1 and f_2, respectively above and below the frequency of half-wave

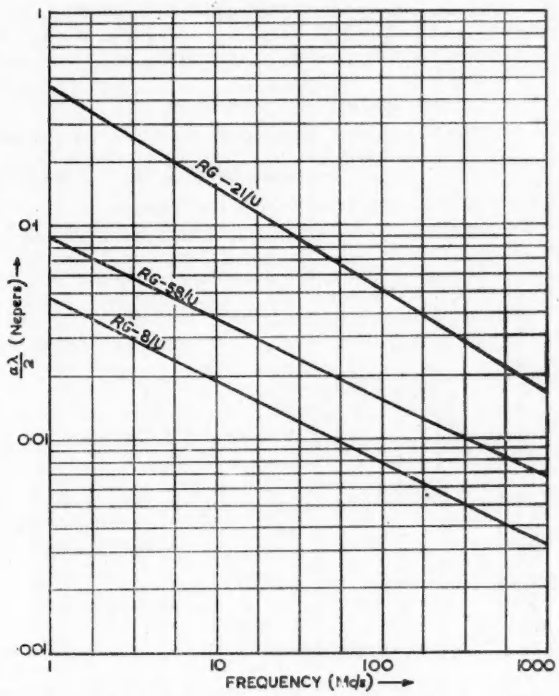
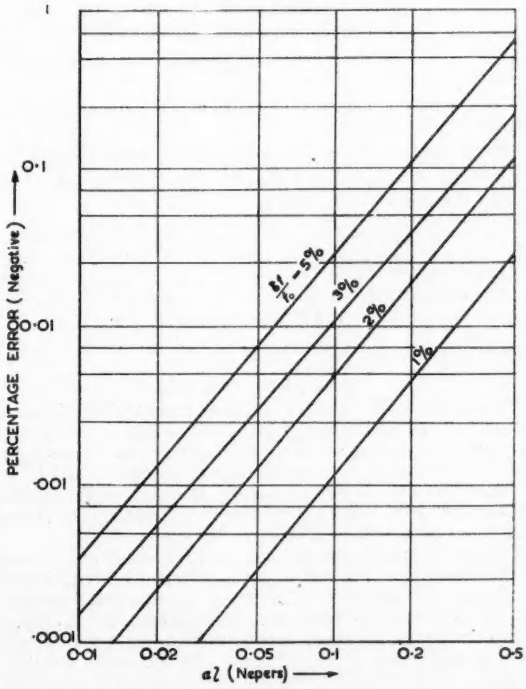


Fig. 2. Attenuation of half-wavelength sections of three types of coaxial cable

Fig. 3. Error of the approximation
$1 + \tanh^2 \alpha l \tan^2 \beta l \simeq 1$



resonance f_o. At each frequency, four magnitudes are read:

CpF—the capacitance resonating with the coil, with the cable disconnected.

Q — of the capacitor-coil combination.

C'pF—the capacitance required to return to resonance after the cable has been connected. This value is read on the "increment" dial of the instrument.

Q' — of the capacitor-coil-cable combination.

The resonance frequency f_o is then computed by interpolation as the frequency for which $C' = 0$. (C', the negative of the cable equivalent capacitance equation (5), is negative at f_1 and positive at f_2). The values of C, Q and Q' at f_o are found by interpolation. The change in Q and Q' will be very small, if any. The input admittance G

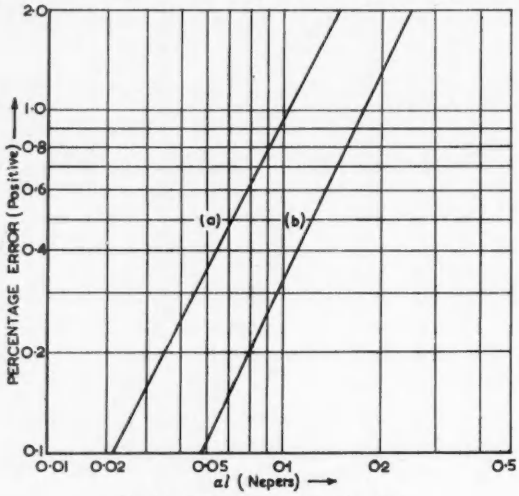


Fig. 4. Errors of the approximations

(a) $1 - \tanh^2 \alpha l \simeq 1$

(b) $\tanh \alpha l \simeq \alpha l$

(at f_o) is then computed, as explained in the instruction manual of the Q-meter.

From equation (5), the capacitance increment C' is:

$$C' = -C = Y_o(-\tanh^2 \alpha l)\ 1/2f_o\ (f_o/f - 1),$$

so that the measured values are:

$$C_1' = Y_o(1 - \tanh^2\alpha l)\ 1/2f_o\ (f_o/f_1 - 1)$$

$$C_2' = Y_o(1 - \tanh^2\alpha l)\ 1/2f_o\ (f_o/f_2 - 1)$$

$$\Delta C = C_2' - C_1' = Y_o(1 - \tanh^2\alpha l)\ 1/2f_o\ (f_o/f_2 - f_o/f_1)$$

$$= Y_o(1 - \tanh^2\alpha l)\ \tfrac{1}{2}\frac{f_1 - f_2}{f_1 f_2}$$

Denoting $f_1 - f_2$ by Δf,

$$Y_o(1 - \tanh^2\alpha l) = 2 f_1 f_2\ \Delta C/\Delta f \quad \ldots . \quad (6)$$

Equations (3), (4) and (6) are used to derive v, Y_o and α.

It should be noted that in equation (6) use is made of a frequency difference. In order to measure it with the required precision, it is advisable to chose f_1 and f_2 as multiples of 1Mc/s, and to set the Q-meter to the desired frequencies with a heterodyne frequency meter that utilizes harmonics of a 1Mc/s crystal oscillator.

Further simplification of equations (4) and (6) is possible if the attenuation is below certain limits. First, $\tanh \alpha l$ may be approximated by αl, and at even lower attenuations ($1 - \tanh^2 \alpha l$) may simply be approximated by 1. Fig. 4 shows the errors of these approximations as a function of αl, and reference to Fig. 2 gives the expected range of values for αl. Generally speaking, for a given cable, the higher the test frequency the better are the approximations involving αl.

End Effects

At the junction between the cable section and the terminals of the Q-meter, a certain end effect may be expected. The effective length of the section may be somewhat different from the physically measured length, and an additional susceptance is effectively shunted across the cable input admittance. These end effects are very difficult to compute, but it is possible to conduct the measurements so as to minimize them. The following procedure was followed to make the measurements for the illustrative example at the conclusion of this article, and the results, when compared with the cable specifications, prove that the precautions were sufficient.

The end of the cable to be connected to the Q-meter was fitted with a coaxial plug (Amphenol type 83-1SPN), and a coaxial socket (Amphenol type 83-1R) was connected to the terminals of the Q-meter. The measurements of C and Q were carried out with an identical plug screwed into the socket; this plug was removed and the cable connected for measuring C' and Q'. The length l was measured from the open end of the cable to the place where the dielectric was removed for mounting the plug.

Illustrative Example

Cable to be tested: Amphenol cable, type RG-8/U.

Test instrument: Q-meter, Boonton Radio Corporation, type 160-A.

Length of sample: $l = 2{\cdot}14$ metres.

Measurements:

	f_1	f_2
	47·0Mc/s	46·0Mc/s
C	52·0pF	54·6pF
Q	270	270
C'	−3·12pF	+1·33pF
Q'	67	67

By interpolation, $C' = 0$ at $f_o = 46{\cdot}3$Mc/s

$$v = 2f_o l$$

$$= 1{\cdot}98 \times 10^8 \text{ metres/second},$$

or, the "velocity factor" of the cable is:

$$\frac{1{\cdot}98 \times 10^8}{3 \times 10^8} = 66 \text{ per cent.}$$

$$\Delta f = 1\text{Mc/s}$$

$$\Delta C = 4{\cdot}45\text{pF}$$

$$Y_o = 2f_1 f_2\ \Delta C/\Delta f$$

$$= 19{\cdot}2 \times 10^{-3} \text{ mho},$$

$$Z_o = 52{\cdot}1 \text{ ohms}$$

At the frequency $f_o = 46{\cdot}3$Mc/s, by interpolation,

$$C = 53{\cdot}8\text{pF}$$

$$Q = 270$$

$$Q' = 67$$

which gives the input impedance of the half-wave section as:

$$G = 0{\cdot}175 \times 10^{-3} \text{ mho}$$

$$\alpha l = G/Y_o = 0{\cdot}00911 \text{ nepers}$$

(this result shows that the approximations made in deriving Y_o are justified).

$$\alpha = 0{\cdot}00426 \text{ nepers/metre}$$

$$\alpha = 0{\cdot}037 \text{ db/metre}.$$

Acknowledgment

The method outlined in this article was developed by the writer during his employment as Visiting Lecturer at the Electronics and Telecommunication Laboratory, Israel Institute of Technology, Haifa.

A Pulse-Interval Meter

for Measuring Pulse Repetition Frequency

(Part 2)

By A. M. Andrew*, B.Sc., and T. D. M. Roberts*, B.Sc., Ph.D.

Power Unit

This is shown in Fig. 8. Transformer T_2 and rectifier V_{32} provide a D.C. supply which is smoothed and then stabilized by the series-parallel valve voltage stabilizer incorporating V_{33}, V_{34} and V_{35}. This gives a stabilized output of 150 volts, of which the positive side is earthed. A voltage-doubler rectifier V_{36} gives a further 20 volts or so by rectifying a 6·3 volt heater supply, and provides a line at −170 volts.

Transformer T_1 and rectifier V_{27} provide a D.C. supply which is stabilized to give outputs at 350 and at 250 volts. The stabilizers giving these outputs use the −150 volt supply as reference voltage.

The high-voltage winding of T_1 has a current rating of 135mA. A current rating of about 80mA would be sufficient, but this transformer is used because it is a standard type which is commercially available.

* *Institute of Physiology, University of Glasgow.*

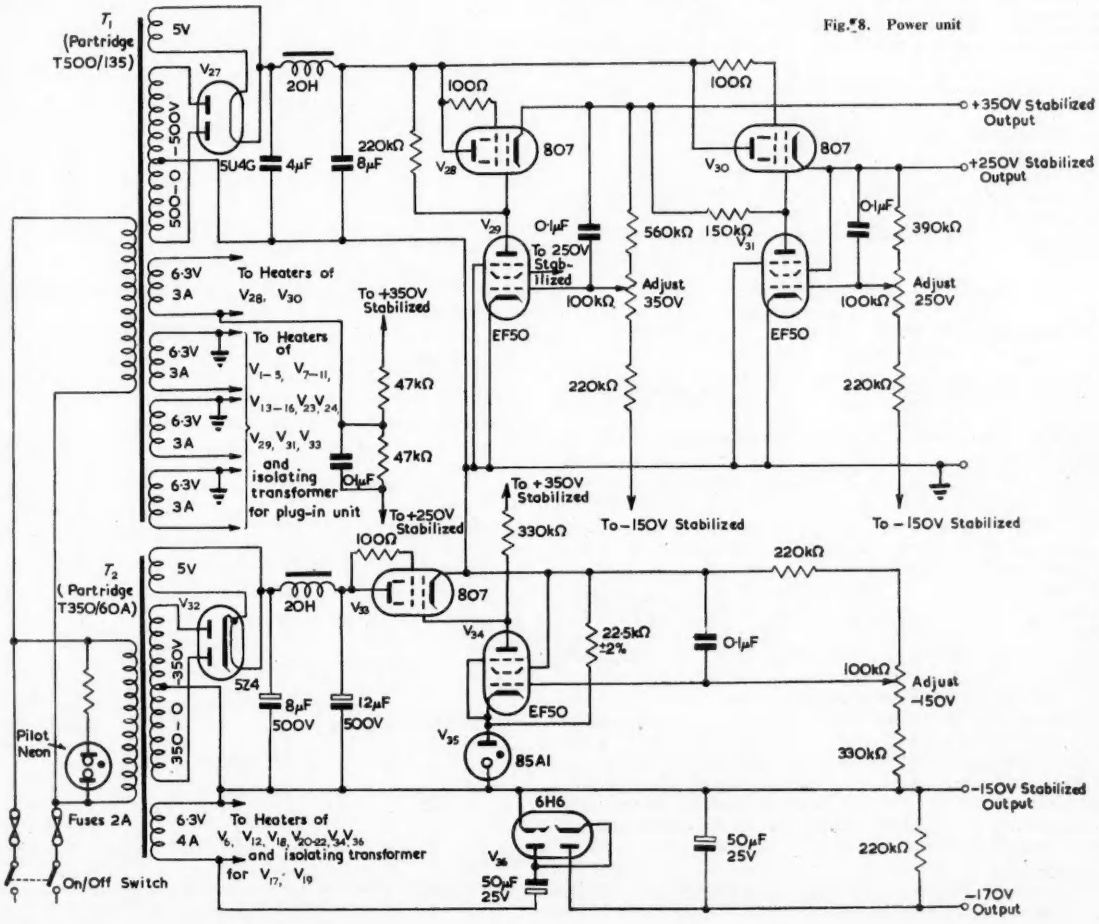
Setting-up Procedure

The supply voltages are first adjusted to their correct values, starting with the −150 volt supply, since this is used as a reference voltage.

To set VR_1 the polarity selector switch is turned to its middle test position. A sine wave of, say, 50c/s is applied to the input of the instrument. VR_1 is adjusted so that the instrument triggers on the smallest possible amplitude of sine wave. The instrument should then be equally sensitive, for a given setting of the gain control, to positive pulses when in the positive pulse position and to negative pulses when in the negative pulse position.

To set VR_2 a high-resistance D.C. voltmeter is connected between V_{23} cathode and earth. With no input to the pulse-interval meter, the voltmeter reads a few volts in excess of 250 volts. A pulse or sine wave input of frequency 100 per second is then applied. VR_2 is adjusted so that the voltmeter reads 50 volts.

Fig. 8. Power unit



Selection of Valve for V_{1B}

Both sections of the double triode V_{1B} should have a sharp cut-off, for otherwise the current which still flows when the section is meant to be cut off will produce a voltage across R_7 or R_8. With the D.C. voltmeter connected between V_{2B} cathode and earth, and with no input to the pulse-interval meter, there should be no observable change in voltage reading when V_{1B} is pulled out. The voltage with V_{1B} in place should be read several times, with some input being applied to the pulse-interval meter between readings, to make sure that the test is satisfactory whichever way the changeover circuit happens to stop.

Different valves should be tried until a satisfactory one is found. Of 11 valves type 6SL7 (various makes) which

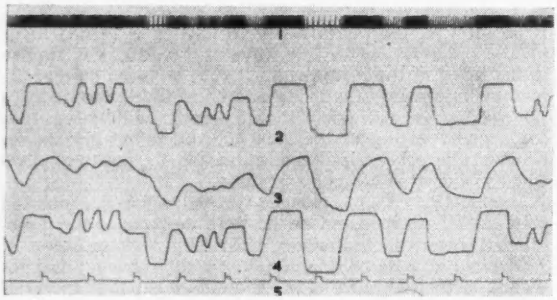


Fig. 9. Comparison of the response of the pulse-interval meter with that of a counting-rate meter to a stream of pulses of rapidly-changing P.R.F. *Trace 1: Pulses from monitor output of pulse-interval meter. Trace 2: Output of pulse-interval meter. Trace 3: Output of counting-rate meter. Trace 4: Position of frequency control of pulse generator. Trace 5: Timing marks at 1-second intervals*

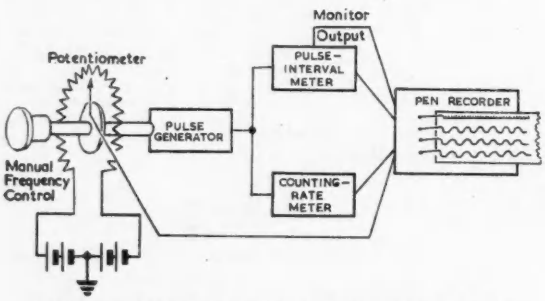


Fig. 10. Arrangement used for making comparisons as shown in Fig. 9

were tried, two were found to be satisfactory. Of 11 Mullard valves type ECC35, ten were found to be satisfactory. The ECC35 is therefore preferred in this position.

Performance

The instrument has proved satisfactory in use. We have not measured the long-term stability of calibration, but any drift which may occur is certainly not enough to be troublesome. The superiority of the instrument over a counting-rate meter is illustrated in Fig. 9, a piece of record taken with the arrangement shown in Fig. 10 as the frequency control of the pulse generator was twiddled. It will be seen that traces 2 and 4 agree fairly closely, but trace 3 is more sluggish. Fig. 11 shows a record of the varying repetition frequency of the impulses from a sense-organ in the cat knee-joint while the knee was rhythmically flexed and extended by a mechanical device (Boyd and Roberts, not yet published). The relation between P.R.F. and the position of the joint is very clearly brought out by the trace obtained with the pulse-interval meter.

Acknowledgments

The pulse-interval meter was constructed using components purchased by a grant from the Carnegie Trust for the Universities of Scotland. The development of the instrument was facilitated by the careful workmanship of Mr. J. J. Brown.

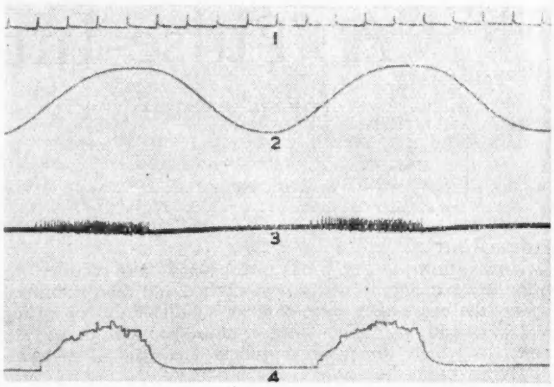


Fig. 11. Record of the response of a sense-organ in the cat knee-joint to mechanical stimulation. *The knee was rhythmically flexed and extended by a mechanical device. Trace 1: Timing marks at ½-second intervals. Trace 2: Record of angular position of the knee-joint. Trace 3: Pulses from the monitor output of the pulse-interval meter (50 c/s interference also appears on this trace owing to a fault in the amplifier driving the pen). Trace 4: Record of pulse repetition frequency given by the pulse-interval meter*

Appendix A

Design of the Charging Network for the Single-Diode Approximation

Values for the resistors in Fig. 12(a) have to be found which will ensure that the capacitor charges approximately according to equation (2), after reaching $V = 50$ at time $t = 1/100$, where V is the voltage across the capacitor.

Consider first Fig. 12(b), where the capacitor C is initially charged to V_A, and the switch S is opened to initiate the discharge at time $t = 1/100$. Let $V_B < V_A$, so that at first the capacitor discharges through both R_A and R_B, but when the voltage across the capacitor becomes less than V_B the discharge is through R_A only. The discharge will be made to conform as nearly as possible to the equation:

$$V = V_A/100t \text{ for } t > 1/100 \quad \ldots\ldots\ldots\ldots \quad (4)$$

The discharge from $V = V_A$ to $V = V_B$ is represented

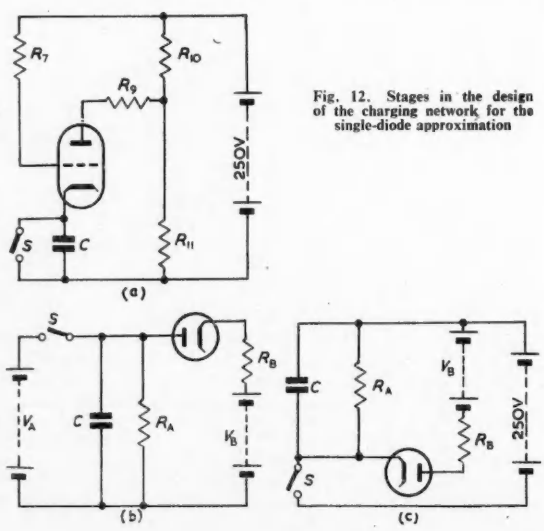


Fig. 12. Stages in the design of the charging network for the single-diode approximation

by:

$$V = V_B \frac{R_A}{R_A + R_B} + \left(V_A - V_B \frac{R_A}{R_A + R_B}\right) \exp -(t - \tau)/R'C \quad \ldots\ldots\ldots\ldots\ldots\ldots (5)$$

where $R' = R_A R_B/(R_A + R_B)$ and $\tau = 1/100$.

Let t_1 be the time (which can be calculated from equation (5)) at which $V = V_B$.

Then the discharge from $V = V_B$ towards $V = 0$ is represented by:

$$V = V_B \exp -(t - t_1)/R_A C \quad \ldots\ldots\ldots\ldots (6)$$

It has been found by trial and error that if

$V_B = 0{\cdot}2475\, V_A$, $CR_A = 0{\cdot}0825$sec, and $CR_B = 0{\cdot}01175$sec . . (7)

the composite curve represented by equations (5) and (6) is very close to the curve represented by equation (4). The curves are shown in Fig. 13.

The value of $0{\cdot}05\mu$F has been chosen for the timing capacitors. Putting $C = 0{\cdot}05\mu$F in equation (7) gives $R_A = 1{\cdot}65$MΩ and $R_B = 235$kΩ.

Now consider Fig. 12(c). In this the circuit of Fig. 12(b) is inverted. The capacitor is charged to 250 volts when S is closed. Suppose S is opened at a time earlier than $t = 1/100$ such that $V = 200$ at time $t = 1/100$. Then $V_A = 200$ volts.

If $V_B = 200 \times 0{\cdot}2475 = 49{\cdot}5$ volts, and R_A and R_B are as above, the voltage across the capacitor is given approximately by (see equation (4)):

$$V = 200/100t = 2/t \text{ for } t > 1/100 \quad \ldots\ldots (8)$$

Now consider Fig. 12(a) once more. Fig. 12(a) differs from Fig. 12(c) in the following respects:—

(a) The diode is replaced by a triode, and R_7, corresponding to R_A, is connected to the grid. A 6SN7 triode with zero grid bias behaves roughly as a resistance of 10kΩ.

(b) R_B and the 49·5 volt battery have been replaced by a resistor network. For the two circuits to be equivalent we must have:

$$R_B = 235\text{k}\Omega = 10\text{k}\Omega + R_9 + \frac{R_{10}R_{11}}{R_{10} + R_{11}} \quad \ldots\ldots (9)$$

and

$$\frac{R_{10}}{R_{10} + R_{11}} = 49{\cdot}5/250 \quad \ldots\ldots\ldots\ldots (10)$$

The 10kΩ term is included in equation (9) to allow for the resistance of the triode valve.

(c) The plate of the capacitor which goes to the positive side of the 250 volt supply in Fig. 12(c) goes to the negative side in Fig. 12(a). Since both sides of the supply are at fixed potentials, this alteration does not affect the working of the circuit, but the voltage across the capacitor, instead of being given approximately by equation (8) is now given approximately by:

$$V = 250 - 2/t \text{ for } t > 1/100 \quad \ldots\ldots\ldots (11)$$

Fig. 13. Comparison of the decay of voltage given by the circuit of Fig. 12(b) (solid line) with the ideal curve represented by equation (4) (broken line)

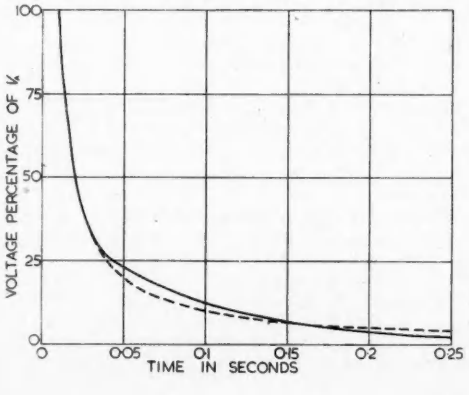
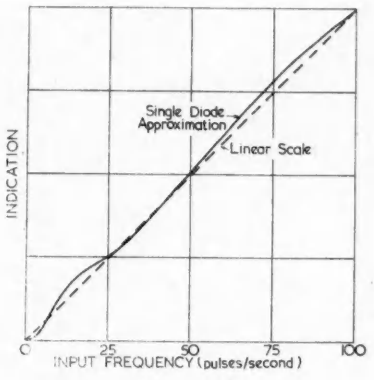


Fig. 14(a). Calculated calibration curve for instrument employing the single-diode approximation

Fig. 14(b). Upper scale: Frequency scale of instrument employing the single-diode approximation. Lower scale: Linear scale for comparison



Since equation (11) is equivalent to equation (2), the desired result has been achieved.

R_{11} has been given the value 470kΩ since this is an approved value. By substituting in equations (9) and (10), and solving for R_9 and R_{10},

$$R_9 = 132\text{k}\Omega,\ R_{10} = 116\text{k}\Omega.$$

Also $R_7 = R_8$ (Fig. 5) = 1·65MΩ, for both R_7 and R_8 correspond to R_A.

These resistance values are used in the practical circuit (Fig. 5).

Fig. 14(a) shows a calculated calibration curve for an instrument employing the single-diode approximation to the desired charging law and conforming to equations (7). Fig. 14(b) shows the form of the frequency scale, with a linear scale for comparison. These figures are drawn from calculated values. The experimental calibration curve and scale are very similar to those shown.

Appendix B

Design of the Charging Network for the Five-Diode Approximation

Values for the resistors in Fig. 7(c) have to be found which will ensure that the capacitor charges approximately according to equation (2), after reaching $V = 50$ at time $t = 1/100$, where V is the voltage across the capacitor.

Consider first Fig. 15(a), where the capacitor C is initially charged to 200 volts and the switch S is opened to initiate the discharge at time $t = 1/100$. The discharge has to conform as nearly as possible to the equation:

$$V = 2/t \text{ for } t > 1/100 \quad \ldots\ldots\ldots\ldots (8)$$

The current leaving the capacitor if equation (8) is obeyed is given by:

$$i = -C\, dV/dt = 2C/t^2$$

i.e.

$$i = CV^2/2 \quad \ldots\ldots\ldots\ldots\ldots (12)$$

The part of Fig. 15(a) to the right of the broken line has to be designed so that the current and voltage are related approximately by equation (12).

The graph of i against V for an arrangement of five diodes, resistors and batteries as shown in Fig. 15(a) is made up of six straight lines. Fig. 16 shows an approximation, consisting of six straight lines, to the curve represented by equation (12). The sections are numbered from the origin outward and the co-ordinates of the "corners" are shown. Values can be assigned to the resistors and battery voltages in Fig. 15(a) such that the relationship between i and V corresponds to this six-line approximation.

If the battery voltages are made to correspond to the voltage co-ordinates of the "corners" of the approximate curve, so that $V_a = 22{\cdot}5$, $V_b = 54$, $V_c = 91$, $V_d = 132$ and $V_e = 173$, the gradient of section 1 of the curve corresponds to the conductance of R_o, the gradient of section 2 to the conductance of R_o and R_a in parallel, and so on. To determine the resistance values it is convenient to tabulate the quantities shown in Table 1.

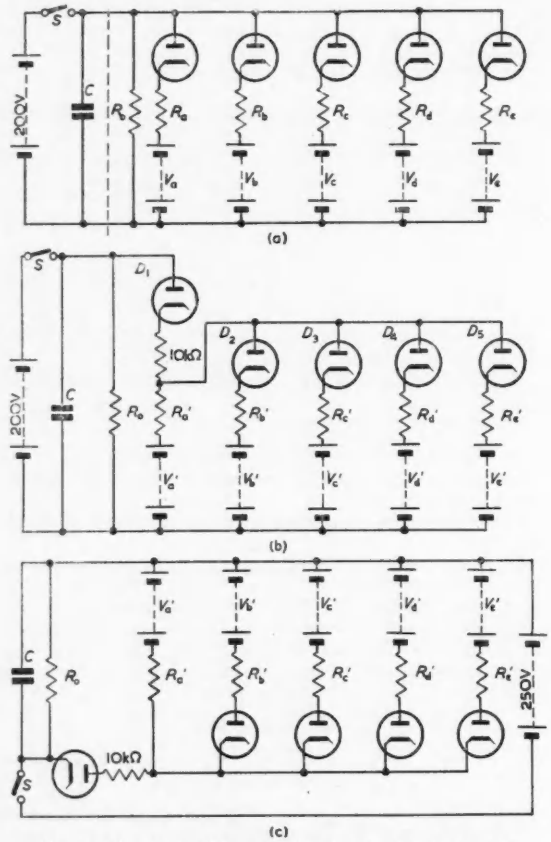


Fig. 15. Stages in the design of the charging network for the five-diode approximation

TABLE 1

SECTION OF CURVE	GRADIENT = CONDUCTANCE	INCREMENT IN CONDUCTANCE	RESISTANCE VALUE	RESISTOR
1	$0{\cdot}444 \times 10^{-6}$	$0{\cdot}444 \times 10^{-6}$	2·25MΩ	R_o
2	1·90 ,,	1·456 ,,	687kΩ	R_a
3	3·65 ,,	1·75 ,,	571kΩ	R_b
4	5·48 ,,	1·83 ,,	546kΩ	R_c
5	7·68 ,,	2·20 ,,	454kΩ	R_d
6	9·45 ,,	1·77 ,,	564kΩ	R_e

With the above values of battery voltage and resistance the circuit of Fig. 15(a) will give a discharge conforming closely to equation (8).

Before deriving values for the practical circuit of Fig. 7(c), however, an additional complication must be introduced. In Fig. 7(c) the four diodes are in series with the triode section, which has an internal resistance of about 10kΩ. Instead of Fig. 15(a), therefore, Fig. 15(b) must be considered.

By an extension of the method used to find values for Fig. 15(a), values have been found for the resistances and battery voltages in Fig. 15(b). They are as follows:

$R_a' = 676\text{k}\Omega$, $R_b' = 546\text{k}\Omega$, $R_c' = 507\text{k}\Omega$, $R_d' = 390\text{k}\Omega$, $R_e' = 478\text{k}\Omega$.

$V_a' = 22{\cdot}5$, $V_b' = 53{\cdot}5$, $V_c' = 89{\cdot}2$, $V_d' = 128$, $V_e' = 167$.

That these values give a discharge conforming to equation (8) can be shown as follows:

Consider the stages in the discharge in the reverse order. For $V < 22{\cdot}5$ none of the diodes conducts, so the conductance $= 1/R_o = 1/(2{\cdot}25 \times 10^6) = 0{\cdot}444 \times 10^{-6}$

When $V = 22{\cdot}5$, diode D_1 starts to conduct.

For $22{\cdot}5 < V < 54$, diode D_1 conducts, so conductance of circuit

$$= 1/R_o + 1/(R_a' + 10\text{k}\Omega) = 1.90 \times 10^{-6}$$

When $V = 54$, diode D_2 starts to conduct, for its anode potential

$$= (54 - V_a') \frac{R_a'}{10\text{k}\Omega + R_a'} + V_a'$$

$$= (54 - 22{\cdot}5)\, 676/686 + 22{\cdot}5 = 53{\cdot}5$$

= its cathode potential.

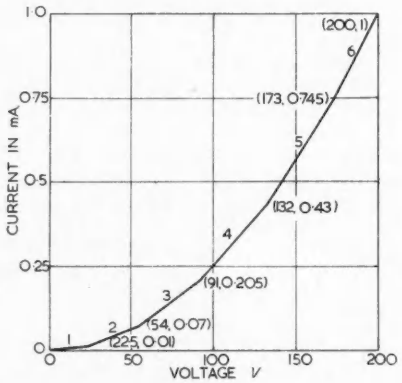


Fig. 16. Approximation, consisting of six straight lines, to the curve represented by equation (12). *The approximation is so close that in a small figure it is not possible to show the exact curve for comparison on the same diagram owing to the thickness of the printed lines*

For $54 < V < 91$, diodes D_1 and D_2 conduct, so conductance of circuit

$$= 1/R_o + \frac{1}{10\text{k}\Omega + R_a'R_b'/(R_a' + R_b')} = 3{\cdot}65 \times 10^{-6}$$

Proceeding in this way it can be shown that the diodes commence conducting in turn at the voltages corresponding to the "corners" in Fig. 16, and the conductance of the network of resistors in which current is flowing corresponds in each voltage interval to the value in column 2 of Table 1. Hence the circuit of Fig. 15(b) is equivalent to that of Fig. 15(a) and will give a capacitor discharge conforming closely to equation (8).

The circuit of Fig. 15(b) is now inverted to give Fig. 15(c), in which the switch S is opened at a time earlier than $t = 1/100$ such that $V = 200$ at time $t = 1/100$. Then the practical circuit of Fig. 7(c) is obtained by transferring one side of the capacitor from the +250 volt line to the −250 volt line, introducing the triode valve, and replacing each resistor and battery by a network of two or three resistors, as was done in deriving Fig. 12(a) from Fig. 12(c). The calculated values for the resistors are shown in Fig. 6. The practical circuit with these values then determines a charging process conforming closely to equation (2).

While operating the pulse-interval meter with the plug-in unit of Fig. 6, the voltage at V_{23} cathode has been plotted against the frequency of the incoming pulses. The graph does not differ significantly from a straight line, the deviations from strict linearity being about one volt at most, in a range of 250 volts.

Appendix C

Obtaining a Non-linear Frequency Scale

The plug-in unit shown in Fig. 17(a) gives a useful non-linear frequency scale. When this unit is plugged in, the circuit of part of the timing units becomes that of Fig. 17(b). The capacitor in either timing unit is simply charged through two resistors in parallel, each of value 2MΩ. With

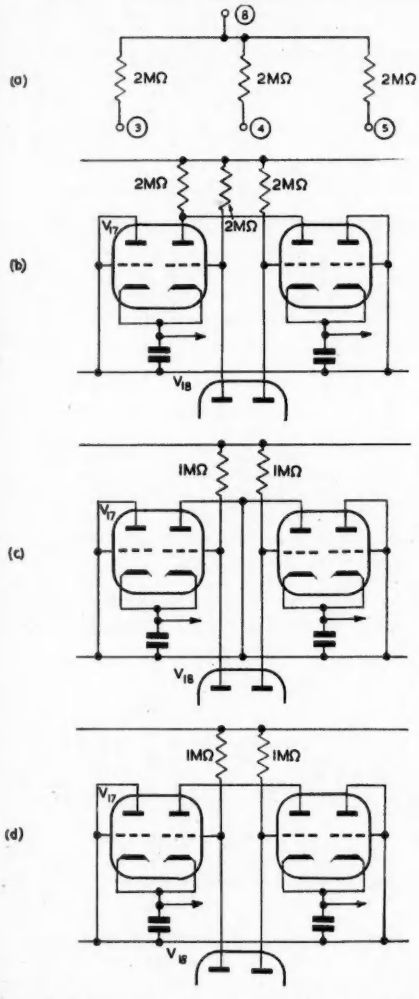


Fig. 17(a). Plug-in unit for non-linear frequency scale

(b). Part of timing units, incorporating plug-in unit of Fig. 17(a)

(c) and (d). Unsuitable alternatives to circuit of Fig. 17(b) (*see text*)

this plug-in unit it is not possible to set VR_2 so that the potential of V_{23} cathode is 50 volts for an input frequency of 100 per sec. If, instead, VR_2 is set so that V_{23} cathode is at 15 volts for this frequency, the frequency calibration curve and scale are as shown in Figs. 18(a) and (b). The circuit of Fig. 17(b) is preferred to those of Fig. 17(c) and (d) for a reason which is dealt with in Appendix D.

Appendix D

The Inverted Triode

When the pulse-interval meter is operated with any of the plug-in units of Figs. 5, 6 or 17(a), the cathode potential of V_{23} corresponding to zero input frequency is one or two volts more positive than the 250 volt line. When it incorporates the circuit of Fig. 17(c) or (d), the potential corresponding to zero frequency is three or four volts more negative than the 250 volt line.

The explanation appears to lie in the fact, pointed out by Terman[6] that the anode potential of a triode valve affects the grid current. In Fig. 17(c), when the cathode potential of V_{17} approaches 250, the anode is about 250 volts negative with respect to the cathode. As can be seen from Fig. 19, when the anode is 250 volts negative the grid current falls to a very low value for values of grid-cathode voltage less than about eight. In the circuit of Fig. 17(c)

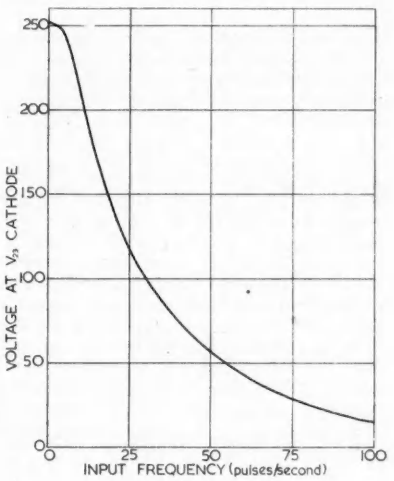
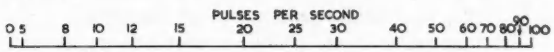


Fig. 18(a). Calibration curve for instrument with plug-in unit of Fig. 17(a)

(b). Frequency scale for instrument with plug-in unit of Fig. 17(a)



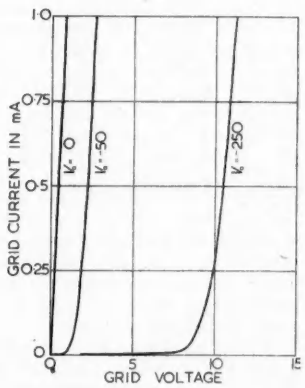


Fig. 19. Grid current characteristics of 6SN7 triode

the capacitor is charged by grid current only. If there is a small amount of leakage from the capacitor, perhaps owing to grid current in V_{23} or to anode current in V_{21}, the charging process will stop when the grid current in V_{17b} falls to a low value.

In the circuit of Fig. 17(d) the potential of V_{17b} and V_{19a} anodes is not known, but the results obtained are similar to those obtained with the circuit of Fig. 17(c).

It appears to be advisable, in order that the frequency scale obtained using the network should be calculable, to design charging networks so that the anodes of V_{17b} and V_{19a} never become highly negative with respect to their cathodes during the charging process. The plug-in unit of Fig. 17(a) conforms to this recommendation.

REFERENCE

6. Terman, F. E. The Inverted Vacuum Tube, A Voltage-Reducing Power Amplifier. *Proc. Inst. Radio Engrs. 16*, 447 (1928).

The Transistor as a D.C. Amplifier for use in Microwave Measurements

By C. F. Davidson*, A.M.I.E.E.

A D.C. amplifier using a junction type transistor is described which enables the sensitivity of a crystal rectifier used for microwave power measurements to be increased. The application of bias to the crystal rectifier causes a further increase in sensitivity.

IN microwave measurement work it is frequently necessary to measure low-level signals; examples of this occur in wavemeters, standing-wave indicators, power monitors, etc. If the microwave signal can be pulsed at an audio frequency no difficulty arises in the detection of low-level signals since a silicon crystal valve rectifier followed by an audio frequency amplifier-detector can be used. If it is not convenient to pulse the microwave signal then a superheterodyne receiver may be employed; this has the advantage of sensitivity but the equipment is relatively complex and a local oscillator has to be tuned. For the measurement of C.W. microwave powers greater than about 1μW a silicon crystal rectifier followed by a galvanometer is adequate.

Use of a D.C. Amplifier to Improve the Sensitivity of the Crystal Rectifier-Galvanometer Arrangement

The use of a silicon crystal rectifier and galvanometer suffers from the disadvantage that the sensitivity is limited by that of the galvanometer and also while galvanometers are satisfactory for use in the laboratory they are not robust enough for field use or for installation in equipment. The use of a D.C. amplifier with a gain of say 30 to 50 times would improve sensitivity and enable the galvanometer to be replaced by a more robust microammeter. A single stage valve type D.C. amplifier is not very satisfactory. Suppose the rectified crystal current is 1μA, the internal resistance of the crystal rectifier at this current level is about 5kΩ so that the internal E.M.F. is 5mV. If this voltage is applied to the grid of a valve with a mutual conductance of 10mA/V the change in anode current is 50μA. This change in anode current is only a small fraction of the total anode current, a backing-off circuit must therefore be used for the indicating meter and a very small change in anode current, due to thermal effects or a change in one or more of the voltages applied to the valve, will produce a serious error in the meter reading. The use of negative feedback in the amplifier reduces the gain while the addition of more stages with negative feedback is a difficult design problem.

The Transistor as a D.C. Current Amplifier

A junction type transistor used with the emitter earthed can produce appreciable current amplification up to perhaps 50 times. The input impedance is low, a few thousand ohms, and the output impedance is high. The basic circuit is shown in Fig. 1. Such an amplifier is obviously ideal for amplifying the current from a silicon crystal rectifier; it has the added advantage that the only power required can be supplied by a three-volt battery.

Fig. 1. The basic circuit

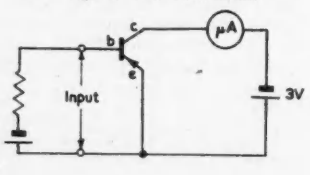


Fig. 2. gives a curve of collector current against input current for a junction type transistor, Mullard prototype OC12, used in the circuit of Fig. 1; it is seen that the current gain is about 35 times.

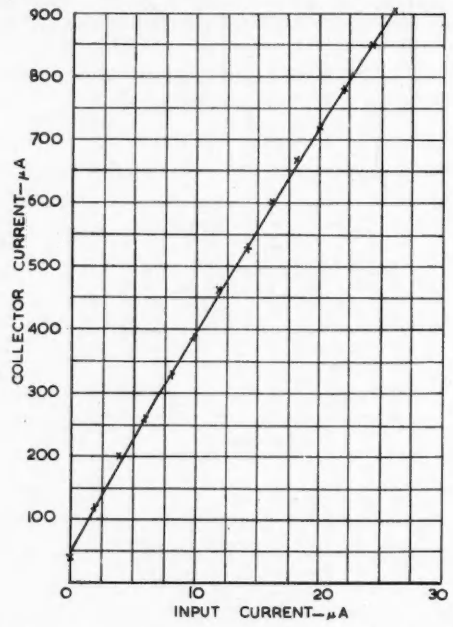


Fig. 2. Collector current/input current for OC12 (emitter earthed)

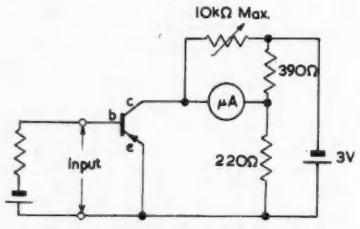


Fig. 3. Backing-off standing current

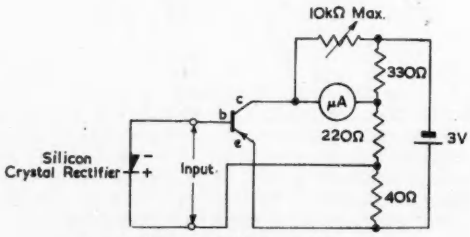


Fig. 4. Method of biasing crystal rectifier

The basic circuit suffers from the defect that with no input current there is a standing collector current. With the transistor used this was about 40μA, but the circuit may be modified as shown in Fig. 3 so that this standing collector current is backed-off.

When the transistor is used to amplify the current from a silicon crystal rectifier the transistor circuit biases the crystal rectifier and reduces its sensitivity. This is readily

* Engineering Dept., G.P.O.

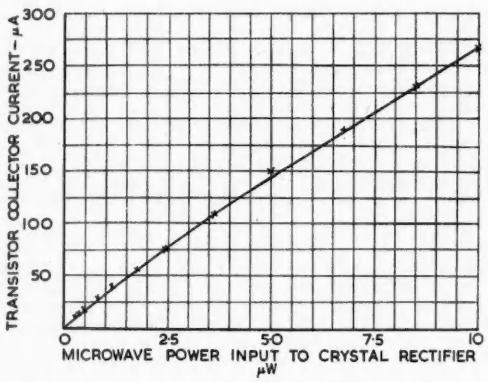


Fig. 5. Collector current/imput power to crystal rectifier

overcome by putting a bias in the opposite direction on to the crystal rectifier, an excess of bias improving the crystal sensitivity. Fig. 4 shows how this can be accomplished.

Fig. 5 shows the manner in which the collector current of the transistor varies with the microwave power applied to the crystal rectifier when used in the circuit of Fig. 4. It is seen that the sensitivity of the arrangement is about $30\mu A/\mu W$. The sensitivity of the crystal rectifier used by itself without bias is $0{\cdot}4\mu A/\mu W$; the effect of the transistor and bias on the crystal rectifier is to increase the sensitivity by a factor of 75.

Conclusions

A junction type transistor D.C. amplifier has been described and a circuit given which will improve the sensitivity of a crystal rectifier used for microwave power measurements by a factor of 75. The use of such a circuit enables the galvanometer, usually used for such measurements, to be replaced by a microammeter. As the impedance of the collector circuit of the transistor is high it follows that the resistance of the microammeter can be several hundred ohms enabling a sensitive and robust meter to be used.

Acknowledgment

The writer is indebted to the Engineer-in-Chief, G.P.O. Engineering Department, for permission to publish the above note.

An Improved Reactance Valve Circuit*

The control of the frequency of an oscillator by means of a reactance valve is a practice that is well known. It is also known that the operation of the simple reactance valve circuit may be improved by using two reactance valves connected in series across the oscillator tank circuit. In this arrangement voltages derived from opposite ends of the tank circuit (and therefore 180° out of phase with each other) are applied respectively to the anodes of the reactance valves, and a voltage of 90° out of phase with one of these is applied to both grids. The two valves simulate reactances of opposite kind, that is to say one will appear as an inductance in the circuit and the other as a capacitance. This form of circuit has the advantage that the presence of the reactance valves does not affect the uncontrolled frequency of the oscillator since the simulated reactances produced by the valves cancel out. Other advantages are that the oscillator output voltage remains much more constant with respect to the frequency control voltage and with respect to supply voltage variations. However, in spite of these useful qualities there has been little tendency to use the circuit since the control voltage must be applied to the two valves in opposite phase and in most practical cases this cannot easily be done.

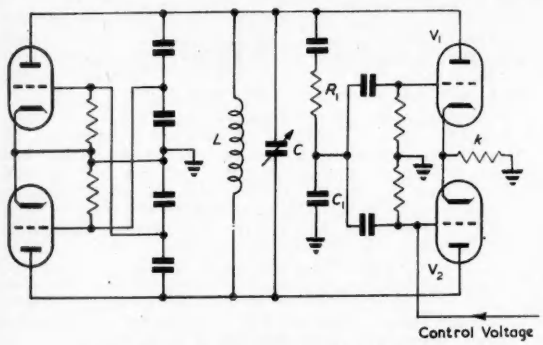


Fig. 1. Method of coupling by common cathode resistor

It has been found that this disadvantage may be simply overcome without the need to add unduly to the number of components in the circuit by coupling the two valves together by a common cathode resistor. In this form of connexion any volage applied to the grid of one valve is also transferred in opposite phase to the other valve.

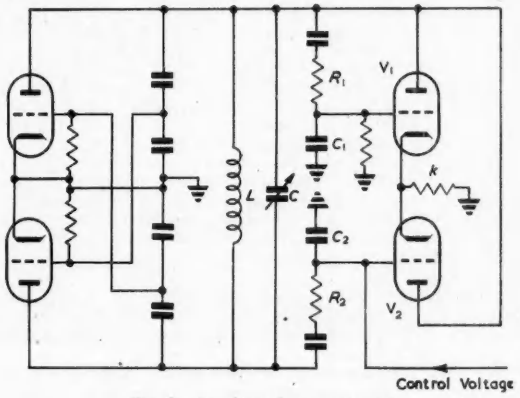


Fig. 2. An alternative arrangement

Two arrangements using the idea are shown in Figs. 1 and 2. In both figures a push-pull form of oscillator is shown in which the tank circuit is denoted by L and C. In Fig. 1 the oscillations are applied in opposite phase to the anodes of the reactance valves V_1 and V_2 which are coupled together by means of the common cathode resistor k, and the network R_1C_1 provides the 90° phase shift for the voltage to be applied to the grids. The frequency control voltage is applied to the grid of valve V_2. In Fig. 2, which shows a simple rearrangement of the circuit of Fig. 1, the anodes of the reactance valves are connected together and in consequence separate networks R_1C_1 and R_2C_2 are employed to provide the quadrature voltages on the grids.

* *Communication from the Telefunken Company, via E.M.I. Ltd.*

TRIDAC

(A Three Dimensional Analogue Computor)

The continuous development of radar and gunnery systems, guided missiles, and high speed aircraft for both civil and military purposes creates a stream of mathematical problems of ever-increasing number and complexity and to solve some of the most difficult of these problems the Ministry of Supply has recently brought into operation at the Royal Aircraft Establishment a new electronic-hydraulic calculating machine or "simulator" called TRIDAC. The name is derived from "Three Dimensional Analogue Computor", and a particular feature is that the machine can deal with problems in which a radar beam or an aeroplane flying under automatic control moves with complete freedom in any direction in space.

TRIDAC, the biggest calculating machine in this country, occupies 6 000 square feet of floor space, uses 8 000 valves, and under peak conditions absorbs about 650kW.

The computor is intended to serve as a research aid for the applied physicist, aerodynamicist and engineer and the basic data available for most of the problems to be studied will rarely be known to better than 1 per cent so that solutions with an error somewhat less than 1 per cent are adequate. In TRIDAC each individual mathematical operation is carried out with an error not greater than 0·1 per cent of full scale. The fact that an analogue machine of the TRIDAC type provides a working model of the system greatly assists the research worker to understand the system and as such it may be regarded as an "aid to physics" or as an "aid to engineering."

The basic analogue quantity in TRIDAC is a direct voltage and the basic element in the majority of the computing units is a high gain D.C. amplifier with input and feedback impedances arranged so as to give an overall transfer function corresponding to addition or integration. To avoid errors due to drift in the amplifiers each amplifier is stabilized by association with a separate drift-stabilizing A.C. amplifier of either the mechanical-chopper or magnetic-modulator type. The gain of the basic D.C. amplifier is of the order of 60 000 and the drift stabilizers can confine the drift to within a few millivolts. To facilitate servicing all the amplifiers and similar units are built in unit form, i.e., on small chassis of approximately 12in by 8in by 3·5in, which slide into arrays of pigeon holes in the cabinets. There are 44 cabinets containing in all about 2 000 units of which approximately 600 are D.C. amplifiers, 350 are mechanical chopper stabilizers and 250 are magnetic modulator stabilizers.

A major section of the computor is a group of nine electrically controlled hydraulic servo motors. Each servo is provided with its own 35 h.p. electric motor and pump delivering oil at 2 000lb/sq.in to the main hydraulic valves. A common low pressure pump supplies oil at 250lb/sq.in to the pilot valves. These high performance servos drive potentiometers. There are about 224 such potentiometers, some of which are directly driven and some of which are driven through sine or cosine linkages. They may be used to multiply voltages appearing in the main electronic computation by the appropriate servo input or by the sine or cosine of the appropriate servo shaft angle, and many of them are used in "axis transformation" calculations.

A central generator room housing rotating machinery supplies power at various voltage levels and frequencies to the entire simulator. The supply voltages are accurately stabilized in individual voltage-stabilizing units before being applied to the computing units. A monitoring system is used to detect and give warning of fault conditions in the computing units.

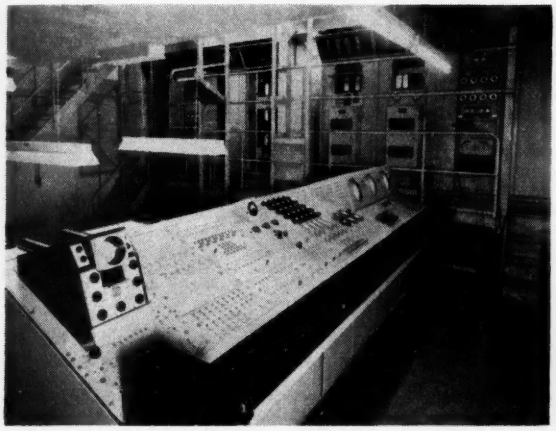
The way in which TRIDAC works may be illustrated by the following examples. Suppose that the forward speed of an aircraft is represented by a voltage on a scale of one volt to ten miles per hour. This voltage, and many others, can be shown on meters, so the speed of the aeroplane in the problem can be observed continuously by watching the meter, and recording devices are provided to give a permanent record when required. The voltage representing forward speed can be fed into an electronic integrator, which produces a second voltage which represents the distance covered by the aeroplane, again according to some pre-arranged scale which might be say, one volt to 100 miles. This voltage also appears on a meter. Alternatively, the voltage representing forward speed might be fed into a resolver into which is also set, either by hand or automatically, the direction in which the aeroplane is flying, say for example 20 degrees north of east. The resolver gives out two more voltages, one representing the rate at which the aeroplane is moving eastward, and the other the rate northward. These two voltages can be fed into two integrators which give output voltages representing distances covered by the aeroplane in the easterly and northerly directions, and by observing these voltages on meters the position of the aeroplane can be plotted on a map. Usually, however, events move too fast for manual plotting and an automatic plotting table is provided. This is a flat board on which runs a carriage moving east and west, and this carriage has a long rail, pointing north and south and carrying a pen which marks a sheet of paper laid on the board. The carriage is moved by the "eastings" voltage so that it travels towards the east by an amount representing the eastward travel of the aeroplane according to the scale of, say, ten miles to the inch. At the same time the pen is travelling along a rail under the influence of the "northings" voltage, so that the pen moves simultaneously east and north, just as the aeroplane does, and the pen traces the path of the aeroplane on the paper. If desired the paper could be replaced by a map of suitable scale. By using a more complicated resolver the variations in height of the aeroplane can be taken into account by feeding in an angle of dive or climb and another plotting table will give a continuous record of the height.

The forward speed of the aeroplane may not be constant, but TRIDAC can still perform the desired calculations no matter how the speed varies, and can indeed go further and calculate the speed from the engine thrust which it in turn calculates from the throttle settings and the engine characteristics, which can be set into the computor by setting a series of controls. These calculations take into account the effects of changing trim of the aeroplane as fuel is used, and the changes of aerodynamic drag and engine efficiency with changing height. Besides varying its forward speed the aeroplane may also vary its direction of flight, and TRIDAC is able to calculate these variations by performing mathematical operations which represent the angles of deflexion of the ailerons, rudder and elevator. These calculations take account of the change of air flow over a wing or control surface when the direction of the flight changes, and also take account of the changes of lift on the wings and other surfaces due to changes of height, speed, and trim of the aeroplane. If the aeroplane is being flown by an auto-pilot the characteristics of this device can be reproduced, and if the aeroplane is using its own radar set to pick up signals from the ground or from another aeroplane the magnitudes of the signals from the radar set can be calculated, allowing for the effects of vibration, interference, etc.

In the case of a fighter aeroplane chasing a bomber the motion of the bomber can be reproduced by setting into the computor a pre-arranged programme, which may include periods of straight flight, slow turns, or violent evasive manœuvres. TRIDAC will then calculate what signals the radar set in the fighter will produce, allowing for the fact that both fighter and bomber are moving at high speed. All the calculations are carried out at the same speed as the actual events occur, so that if the fighter-bomber interception takes ten minutes

in actual flight then TRIDAC will do the calculation in ten minutes. While the calculations are proceeding all the quantities in the problem are available as voltages, and can be observed by means of meters, plotting tables, cathode-ray tubes, etc., so that the operator can get an excellent picture of what is going on. He can stop the calculation at any time, and he can repeat as often as he wishes, using different kinds of aircraft by setting different aerodynamic characteristics, different speeds for fighter and bomber, different starting positions, etc., so the chance of an interception in any given circumstances can be found, and the most favourable tactics can be discovered. Similar calculations can be performed for guided missile systems, including beam-riding, homing, and command-link systems. The use of TRIDAC for this purpose will reduce the number of actual missiles which need to be fired for test purposes, with a consequent saving in time and expense.

Since TRIDAC works in the same time scale as the real system, actual equipment, such as the motor which moves the ailerons in a powered-control aeroplane, can be included in the operation of the computor. A voltage in TRIDAC which represents the input signal to the aileron motor is brought out and fed into the actual motor which may move either a real aileron or a dummy. The aileron carries a potentiometer which provides a voltage proportional to the angle through which the



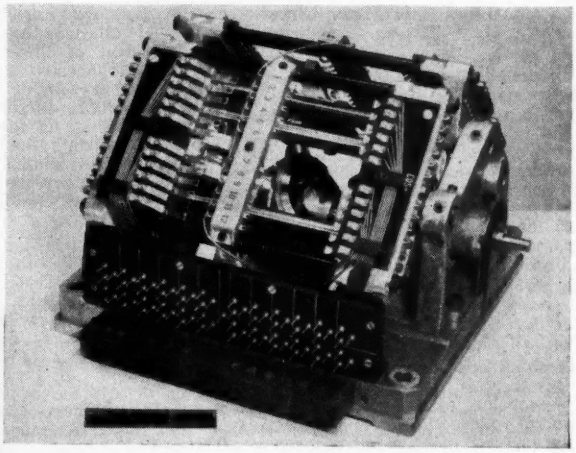
A general view of TRIDAC, showing the control desk with the three-dimensional display at the right-hand end

aileron turns, and this voltage is passed back into the computor for the calculation of rate of roll, etc. This procedure allows measurements to be made of the effect of using different kinds of aileron motors. The pilot of the aeroplane can also be included when required. He is provided with "displays" of radar and instrument information, operated by signal voltages from TRIDAC, and he operates controls of the normal type which drive potentiometers to give another set of voltages to be fed back into TRIDAC.

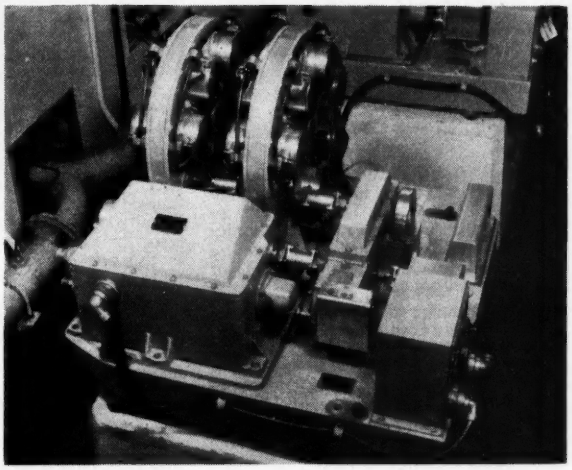
One of the central parts of the problems which TRIDAC has to handle is that of "axis transformation", which involves complex geometrical and trigonometrical calculations. In the fighter bomber problem the fighter-borne radar dish normally points ahead, but when the bomber comes into range the dish must be turned, say, 20 degrees to the right and then tilted, say, 15 degrees downward. These angles are measured with reference to the frame of the fighter, and if the fighter turns or dives these angles will change, because the auto-follow action of the radar keeps the dish pointing continuously at the bomber. In many TRIDAC calculations it is necessary to know the direction in which the radar dish is pointing, in terms of an angle from the true north and a depression or elevation relative to the true horizontal. To do this TRIDAC takes the angles of the dish as measured with reference to the frame of the fighter, and also takes the two angles which represent the direction in which the nose of the fighter is pointing, i.e. the bearing relative to true north and the angle of climb or dive relative to the true horizontal. This second pair of angles is available from another part of the machine which is calculating the flight path of the fighter. From the two pairs of angles TRIDAC is able to find the direction in which the dish is pointing, referred to true north and horizontal. This calculation proceeds continuously, since the position and attitude of the fighter and the position of the bomber are changing continuously.

Before any calculations can begin on TRIDAC a large amount of information has to be supplied. In the case of numbers which will not change as the problem proceeds, such as the size of an aeroplane wing, or relation between the rudder deflexion and the rudder-bar deflexion, there are up to 2 000 potentiometers which can be set before calculation begins. For known variations, such as the change of speed of sound with height, specially shaped cams and potentiometers are provided. Adjustable electronic apparatus using sets of biased diodes are used for other non-linear variations.

TRIDAC has been designed jointly by R.A.E. and Elliott Brothers (London) Limited, and it has been constructed by Elliott Brothers and installed at the R.A.E. It will be operated by R.A.E. staff, and will be available to help industry in the same way as wind tunnels and other major items of research equipment.



Swash-plate sine-cosine mechanism.



Hydraulic servo driving a number of slave linear potentiometers.

LETTERS TO THE EDITOR

(We do not hold ourselves responsible for the opinions of our correspondents)

A Count-Rate Meter Circuit

DEAR SIR,—Mr. E. W. Pulsford's article on an ingenious method of correction for dead time losses in count-rate meters (page 356, August issue) omits a point which seems to extend the application and utility of the system. As is well known, the diode pump and D.C. amplifier metering system is not absolutely linear owing to the finite amplifier gain. Using Mr. Pulsford's symbols the signal voltage at the anode of V_3 in the absence of compensation can be expressed in the form

$$v = AVn \cdot \frac{R_t C_t/(\beta A + 1)}{1 + nR_t C_t/(\beta A + 1)} \quad \ldots (1)$$

where A is the amplifier gain without feedback and βA is the loop gain across R_t. It is of interest to note that, for given values of R_t, V, A and maximum output voltage, the non-linearity expressed by this equation is independent of β, since C_t must be made proportional to $(\beta A + 1)$. If, while maintaining the full feedback connexion of C_t, the right-hand end of R_t is earthed, β is then zero and the circuit becomes a type of Miller integrator; this form, however, suffers from poor stability of gain and zero.

Writing $T = R_t C_t/(\beta A + 1)$
and $n = N/(1 + Nt)$ we have

$$v = AVN \cdot \frac{T}{1 + N(t + T)} \quad \ldots (2)$$

This equation shows that the inherent non-linearity of the diode pump and D.C. amplifier system is equivalent to increasing the dead time t by the quantity T. Mr. Pulsford's circuit can therefore be adjusted to eliminate this source of inaccuracy without any modification.

The percentage departure from non-linearity, due to both dead time and diode pump, is approximately $-100N(t+T)$ per cent. In the circuit described T is probably about $0{\cdot}1t$. The fact that both sources of inaccuracy can be exactly eliminated by the same circuit allows additional freedom in the design of the diode pump metering system.

Yours faithfully,

B. D. CORBETT,

Dept. of Clinical Research,

University College Hospital Medical School.

The Author replies:

DEAR SIR,—I am indebted to Mr. B. D. Corbett for pointing out that the circuit of the count-rate meter which corrects for dead-time losses, is also capable of correcting the inherent non-linearity of the scale, and I am in full agreement with his analysis.

There is a simple way of calculating the linearizing voltage to be fed back to the diode pump driving wave. When the signal voltage at the anode of V_3 is v, the movement of the input grid from its initial voltage is $-v/A$, where A is the gain of V_3, without feedback. This grid voltage shift is effectively subtracted from the amplitude of the driving wave, and so to maintain the effective amplitude constant, v/A must be added to it, which can be done by the appropriate adjustment of the circuit, as Mr. Corbett notes.

It is doubtful if it is worth the extra complication in a simple count-rate meter, but if a dead-time compensating instrument is being set up, it might be worth going to the trouble of setting in this linearizing feedback before proceeding to adjust for the dead-time compensation. In the experimental model the departure from linearity, as read on a first grade meter, was quite small, and this is the common experience with this type of rate-measuring circuit.

A further extension of the utility of this system is believed to exist, although the analysis is not yet complete. In the counting of random-in-time pulses with a count-rate meter not having any intentional resolving time, some losses always occur because of the incomplete charge or discharge of the diode pump feed capacitor when the pulse spacings are of the same order of magnitude as the charging time-constant ($C_t R_4$). Our analysis so far leads us to believe that the instrument behaves as though it has an effective resolving time equal to this time-constant, although none is intentionally provided. In the cases where a resolving time is provided it is lengthened by this time-constant, and therefore losses from both these causes may be compensated by the method of the article. (Reverting to the instrument described, having an intentional resolving time of 10μsec, and a charging time of 2μsec, it might be more accurate to adjust for an effective resolving time of 12μsec). Should this prove to be the case, then more accurate count-rate meters for dealing with the very fast count-rates from scintillation counters could be designed economically. It should be stressed that the remarks of this paragraph refer only to the counting of random-in-time pulses.

In conclusion, I must apologize for a small error in Fig. 3, page 357, where a high potential terminal of R_4 should be connected to the cathode of V_3, and not to the junction of R_6 and R_7.

Yours faithfully,

E. W. PULSFORD,

A.E.R.E., Harwell.

Output Impedance of Anode-Follower Type Circuits

DEAR SIR,—I find that some text books quote the output impedance of the circuit of Fig. 1 as being $Z_o = 2/g_m$ or to be some value which to a first approximation does not include R. Below is a simple but complete analysis which shows the output impedance to be proportional to R.

Let $\beta = \dfrac{R_1}{R_1 + R_2}$

Let A be the gain of the circuit from the grid to the anode when the output

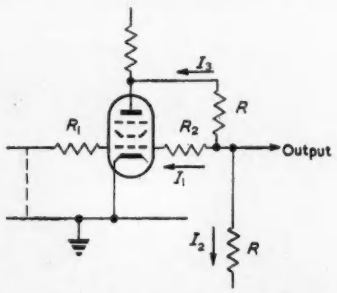


Fig. 1. Circuit for calculating output impedance of anode-follower

point is shorted to earth and R between the anode and output is replaced by $\dfrac{A\beta \cdot R}{A\beta + 1}$ (which is approximately equal to R).

If the output voltage is changed by ΔV the current will be split between R_1 and the two R's, I_1 and I_2 are given by $\dfrac{\Delta V}{R_1 + R_2}$ and $\Delta V/R$ respectively.

The current I_3 is given by:

$$\Delta V/R + \frac{AR_1}{(R_1 + R_2)} \quad \Delta V/R$$

adding the currents and dividing by ΔV gives:

$$1/Z_o = \frac{1}{R_1 + R_2} + 1/R + 1/R + \frac{AR_1}{(R_1 + R_2)R}$$

giving:

$$Z_o = \frac{RR_1}{\beta R + R_1(2 + A\beta)}$$

for all practical purposes. βR can be neglected compared with $R_1(2 + A\beta)$ giving:

$$Z_o \simeq \frac{R}{2 + A\beta}$$

and again $A\beta$ is always very much greater than 2, giving:

$$Z_o \simeq R/A\beta$$

This result does not agree with that very often quoted.

Yours faithfully,

D. McDONNELL,

Weybridge, Surrey.

The Design of High Efficiency Radio Frequency E.H.T. Supplies

DEAR SIR,—In view of the correspondence upon this subject published in the November issue, the author feels that a detailed calculation of one of the original examples given in the article would clarify the design process considerably. In the simple case where E.H.T. only is required, and no heaters have to be supplied, the calculations are perfectly straightforward. To indicate the influence of other windings upon the design, a detailed calculation of example 2 in its corrected form follows:

The required supplies are 6·6V D.C. at 2mA, 4V 2A for C.R.T. heaters, and two floating supplies of 300V D.C. at 10mA.

Here the A.C. load on the E.H.T. coil due to the D.C. load is $6{\cdot}6/4 = 1{\cdot}65\text{M}\Omega$. This would indicate the choice, from Table 2 of the 1 600 turn coil, but in the present case the loads on the other windings are reflected across the E.H.T. coil by the transformer, and reduce the Q factor as seen by the oscillator valve. These reflected loads lead to a choice of the 800 turn coil, when the reflected A.C. loads can be found by means of voltage ratios.

Using the 800 turn coil we have volts per turn $= \frac{6\,600}{800\sqrt{2}}$ R.M.S. $= 5{\cdot}82$. Thus the two heater windings will each have 1 turn. In order to produce 4V for the C.R.T.s, a small auto-transformer wound on a miniature Ferroxcube core was used, to avoid undue power loss. For the rectifier heater, a dropping resistor was used, the valve requiring 1·4V at 0·14A.

The reflected loads are then as follows:

From rectifier heater $\frac{5{\cdot}82}{0{\cdot}14}\left(\frac{6\,600}{5{\cdot}8\sqrt{2}}\right)^2 \times 10^{-6} = 26{\cdot}7\text{M}\Omega$

From C.R.T. heater $4/2\left(\frac{6\,600}{4\sqrt{2}}\right)^2 \times 10^{-6} = 2{\cdot}72\text{M}\Omega$

From each 300V winding 15 000 $\left(\frac{6\,600}{300}\right)^2 \times 10^{-6} = 7{\cdot}26\text{M}\Omega$

The effective A.C. shunt is therefore $0{\cdot}777\text{M}\Omega$.

Thus with the 800 turn coil we have $Q = \frac{0{\cdot}777}{0{\cdot}069} = 11{\cdot}25$, $\eta = \frac{100 \times 43{\cdot}3}{43{\cdot}3 + 1{\cdot}65} = 96{\cdot}5$ per cent.

The remaining data originally given for this example are correct.

Yours faithfully,

J. BARRON,

University of Cambridge, Department of Physics.

Multi-stage Amplifier Output Impedance

DEAR SIR,—The ratio of the net amplification to the parallel output impedance of a simple amplifier, both with and without voltage feedback is a constant. When this result is applied to the case of a multi-stage amplifier with over-all voltage feedback, a simple expression relating the parallel output impedance to the amplifier constants is obtained.

The stage gain A, of a simple amplifier can be expressed by the relationship: $A = \mu Z_L/(r_a + Z_L)$ where μ and r_a refer to the valve constants, and Z_L is the load impedance. As the mutual conductance of the valve $g_m = \mu/r_a$ an alternative expression can be obtained which states that $A = g_m r_a Z_L/(r_a + Z_L)$. By definition the parallel output impedance $Z_p = r_a Z_L/(r_a + Z_L)$ so that:

$$A/Z_p = g_m \quad \ldots\ldots\ldots\ldots (1)$$

(Parallel output impedance Z_p is used to mean the impedance between the output terminals with the load still connected. The normal output impedance Z_o is always measured with the load disconnected.

The relationship connecting the two output impedances is obviously:

$$1/Z_p = 1/Z_o + 1/Z_L$$

where Z_L is the load impedance.

N.B.—The expressions developed hold only for voltage feedback and not for circuits using current feedback.)

When feedback is employed, so that a fraction β of the output voltage is returned to the input, the net gain:

$$A' = A/(1 - \beta A) \quad \ldots\ldots\ldots (2)$$

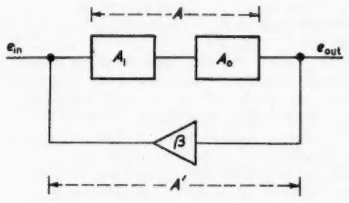


Fig. 1. Multi-stage amplifier with voltage feedback

and the new parallel output impedance:

$$Z_p' = Z_p/(1 - \beta A) \quad \ldots\ldots\ldots (3)$$

so that dividing equation (2) by equation (3) we have:

$$A'/Z_p' = A/Z_p = g_m \quad \ldots\ldots\ldots (4)$$

Hence the ratio of the net gain to the parallel output impedance is equal to the mutual conductance of the valve. Equations (2) and (3) are dependent upon the nature of the feedback, and β will be negative for negative voltage feedback, but the term involving β does not appear in equation (4), so that this result is independent of the nature of the feedback employed.

The result becomes of interest when applied to a multi-stage amplifier. If we split the amplifier into two sections; one, from the input to the grid of the last stage, having a gain of A_1, and the other, the output stage, having a gain of A_o, then the total amplification $A = A_1 A_o$ and the parallel output impedance $Z_p = A_o/g_m$ where g_m applies to the last stage only.

If a voltage feedback is connected, as shown in Fig. 1, the total gain of the amplifier is now A', and by comparison with equation (2) and (3) it can be seen that:

$$A' = A/(1-\beta A) = A_1 A_o/(1 - \beta A_1 A_o) \quad \ldots\ldots\ldots (5)$$

and that the new parallel output impedance is:

$$Z_p' = Z_p/(1-\beta A) = Z_p/(1 - \beta A_1 A_o) \quad \ldots\ldots\ldots (6)$$

Dividing equation (6) by equation (7) it can be seen that $Z_p'/A' = \frac{Z_p}{(A_1 A_o)}$ and since in this case $Z_p/A_o = 1/g_m$, if g_m is the mutual conductance of the last stage, therefore $Z_p'/A' \doteq 1/g_m \,.\, 1/A_1$ or the parallel output impedance:

$$Z_p' = 1/g_m \,.\, A'/A_1 \quad \ldots\ldots\ldots (7)$$

In the more useful case where the voltage feedback is negative, A' is constant if the relationship $\beta A_1 A_o \gg 1$, which means that the parallel output impedance of the multi-stage amplifier will then be independent of the load in the last stage, as A_o does not enter into the expression.

If the multi-stage amplifier is reduced to a single stage, then $A_1 = 1$ and the parallel output impedance reduces to the value for the simple case in equation (4).

A simple example is the cathode-follower which has a gain very nearly equal to 1, and by means of equation (7) the parallel output impedance can be seen immediately to be $1/g_m$ which is, of course, the well-known value.

More precisely, the gain is equal to $g_m/(1/R_k + 1/r_a + g_m)$, where R_k is the cathode load, and the parallel output impedance can quickly be recognized as $1/(1/R_k + 1/r_a + g_m)$.

The design conditions for an amplifier with a gain of 1 000 and a parallel output impedance of 1 ohm can be easily calculated from equation (7) by treating A_1 as the unknown. If we chose a valve with a mutual conductance of 5mA/V for the last stage then:

$$A_1 = 1/g \,.\, A'/Z_p' = \frac{1\,000}{5 \times 10^{-3}} = 2 \times 10^5$$

and

$$\beta = -1/A' = \frac{-1}{1\,000} = -10^{-3}$$

The condition that $\beta A_1 A_o \gg 1$ is satisfied if $A_o > 1/20$, so that the load of the last stage can have almost any value. In practice it would be chosen so that the current flowing through the valve gave the desired value of g_m.

Reduction of the output impedance by these means only reaches a limit when the amplifier becomes unstable due to phase changes in the feedback network.

Yours faithfully,

J. B. EARNSHAW,

Physics Department,

Auckland University College, New Zealand.

ELECTRONIC EQUIPMENT

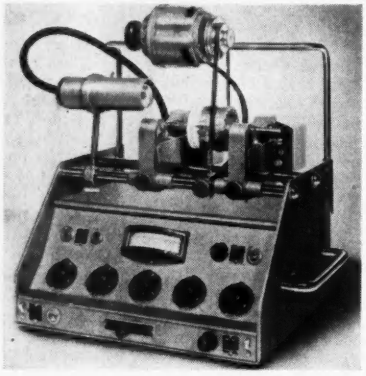
A description, compiled from information supplied by the manufacturers, of new components, accessories and test instruments.

Strobodynamic Balancing Machine

(Illustrated below)

TWO models of a balance testing machine of special interest to the electric motor, aircraft and motor car industries are announced by E.M.I. Engineering Development Ltd.

The equipment is simple and positive in use. The rotor to be balanced is supported in the open bearings of two freely-suspended cradles and belt driven by an electric motor. By means of special circuits, the unbalance produces an electrical signal which is arranged to flash a stroboscopic lamp which illuminates the workpiece under test. It thus appears stationary, with the position of the unbalance indicated against a pointer;



at the same time, the signal actuates a meter to indicate the amount of unbalance.

The Type 1 machine takes loads up to 30lb, with a maximum diameter of 11in and maximum length between bearings of 14in. Balancing speed range is 1 000 to 2 500rev/min.

The Type 2 (illustrated) machine has a similar speed range, but the other maxima are: weight of load 7lb; diameter 4in; length between bearings 8¼in.

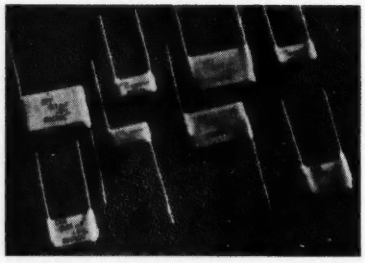
E.M.I. Engineering Development Ltd, Wells, Somerset.

Silvered Mica Capacitors

(Illustrated above right)

INTENDED primarily for applications where long-term stability is essential, the Johnson Matthey range of new design capacitors takes advantage of increased electrode areas and lower voltage rating to bring about a reduction in both bulk and cost.

These capacitors are rated at either 200 or 350V peak working and are of fired construction, thus completely obviating the use of eyelets. They are impregnated with a wax suitable for use over the temperature range −30 to +70°C and a coating of the same wax is used to protect them.



Three overall sizes from 1 11/16in by 1¼in to 1 1/16in by 9/16in are available and for each size there are two possible lead arrangements (see illustration). Any value of capacitance in the range 300pF to 0·25μF can be supplied with a minimum tolerance of ±½ per cent.

Johnson, Matthey and Co, Ltd, 78 Hatton Garden, London, E.C.1.

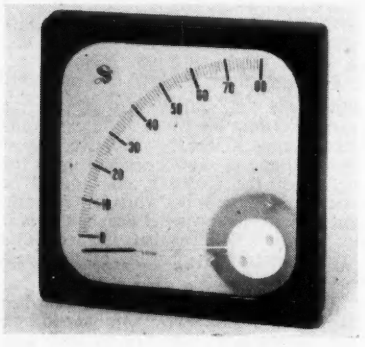
Quadrant Meter

(Illustrated below)

A RECENT addition to the range of electrical measuring instruments manufactured by Measuring Instruments (Pullin) Ltd. is the quadrant meter. It is ideal for use where a long scale instrument is required on equipment having a very limited interior space available as it occupies the same space behind the panel as a conventional meter with a 2in scale but, with a front projection less than 1in, has a scale length of 7in.

The dial which can be supplied in various colours to customers specification is made of a special translucent material and is unbacked. This, together with the positioning of the movement in the corner of the dial facilitates illumination from the back of the instrument and results in a uniform spread of light over the whole scale.

The quadrant meter is available as a milliammeter or ammeter with any range from one milliamp upwards or as a voltmeter and can be supplied with a moving-coil movement for D.C. circuits



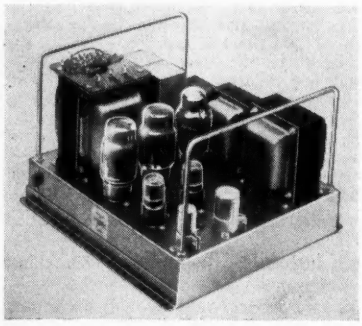
or a rectifier can be incorporated for use on A.C. This meter complies in all respects with B.S.89:1954 for industrial grade instruments.

Measuring Instruments (Pullin) Ltd, Electrin Works, Winchester Street, Acton, London, W.3.

Wideband Audio Amplifier

(Illustrated below)

AN engineered version of the Williamson amplifier is now being produced by Radford Electronics. In addition to its normal audio uses this amplifier is suitable for use on low frequency vibration and ultrasonic research. The frequency response is



claimed to be flat within ±2db from 5c/s to 300kc/s and the distortion less than 0·1 per cent at 15W output. The standard output transformer provides output impedances of 1·7, 6·8, 15·3, 27, 42·5, 61, 83 and 109Ω, but other impedances can be supplied to order.

Radford Electronics Ltd, 149 Newfoundland Road, Bristol, 2.

Miniature and Sub-miniature Precision Potentiometers

TWO new precision potentiometers have been added to the range recently introduced by Salford Electrical Instruments Ltd. They comprise linear miniature and sub-miniature types, and have been developed for use in applications where space is particularly limited.

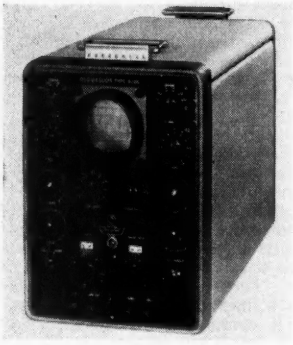
The miniature potentiometer, the D.2, though it weighs 15g and is only 1½in in diameter, covers a resistance range from 1kΩ to 90kΩ and has a power rating of 1W. The maximum resolution obtained is 6 turns/degree and the standard electrical angle is 340°. There are two taps on the standard model, each being made to a single turn of wire. The housing is fitted with a keyed locating spigot and this allows up to three units to be ganged on a single shaft. The torque with plain bearings is approx. 5g.cm, but ball bearings can be fitted

if necessary and the torque is then of the order of 2 to 3g.cm.

The sub-miniature potentiometer, known as the S.D., features a special resistance card and clamp ring assembly. The complete potentiometer weighs only 4g and measures $\frac{3}{8}$in in diameter by $\frac{1}{2}$in in length; the latter measurement is taken from the front of the case to the rear of the housing and does not include terminal or spindle projection.

The resistance range covered by this instrument is from 200Ω to 8kΩ. The maximum resolution is 2 turns/degree and the power rating $\frac{1}{4}$W. There are two taps and the electrical angle is 280°. The sub-miniature potentiometer cannot be ganged, and is essentially a "trimmer" and unsuitable for servo application. It can, however, be supplied with a $\frac{1}{4}$in long shaft or with a screw adjustment as required.

The General Electric Co, Ltd,
Magnet House,
Kingsway,
London, W.C.2.



Servo and General Purpose Oscilloscope

(Illustrated above)

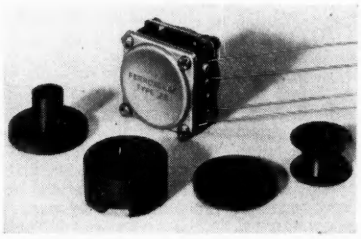
THE model 0·100 oscilloscope has been developed from the type 1684D/2 and retains its main features, viz: symmetrical, direct-coupled, X and Y amplifiers (zero to 4Mc/s), instantaneous shift with high datum stability and functional independence of controls. In addition, the 0·100 embodies a triggered time-base, together with calibrated time and voltage measurement. It is also suitable for photographic recording as well as direct observation of both transient and recurrent phenomena. Cameras suitable for single shot or continuous film trace photography are available.

Furzehill Laboratories Ltd,
Shenley Road,
Boreham Wood,
Hertfordshire.

High Q Inductors

(Illustrated above right)

THE Components Division of Mullard Ltd. can now supply a wide range of ready-wound high Q inductors. Most of these are on Ferroxcube pot core assemblies and are suitable for use at frequencies from 300c/s to about 500kc/s. In due course, additional types will become available which will extend both the frequency and inductance ranges.



Owing to the low material hysteresis loss, it is possible, with very high values of inductance, to obtain extremely high values of Q, for example, a Q of 700 at 10kc/s.

In addition to high efficiency, coils on Ferroxcube pot cores have the advantage of compactness. A 20H inductor may be wound on a core with overall dimensions of 1 1/16in by 1 1/16in by $\frac{3}{4}$in, including all necessary clamping screws.

The inherent self-screening effect of Ferroxcube, due to its high material permeability, makes it possible to stack coils or place them near other components without danger of stray inductive coupling. This property makes them particularly useful for compact, efficient filters.

Mullard Ltd,
Century House,
Shaftesbury Avenue,
London, W.C.2.

Differential A.C. Ammeter

THIS instrument is sensitive enough to indicate a difference of 1A between two A.C. circuits each carrying 1 000A or 5μA between two circuits each carrying 5mA.

It consists of a centre zero moving-coil instrument and two bridge rectifiers, the output of these being in opposition and connected to the moving-coil instrument. Usually each rectifier is connected with its A.C. side to the output of a transformer, the transformers being well balanced and identical in every characteristic.

The Electrical Instrument Co. (Hillingdon) Ltd,
Boswell Square Industrial Estate,
Hillingdon, Glasgow, S.W.2.

Klystron Power Supply Unit

(Illustrated below)

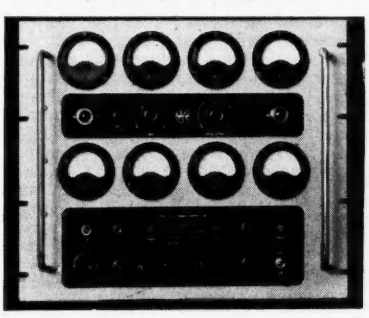
THIS power supply unit has been developed to furnish all the voltages necessary for the operation of equipment containing klystrons under development conditions. Each supply is fully and independently metered, and all are insulated for use at a minimum potential of 2·5kV to earth, positive or negative. The following voltages are available, with reference to the klystron cathode :—

E.H.T. Adjustable from 1kV to 2·5kV, at from zero to 15mA. Internal resistance not exceeding 500Ω, and regulation for changes of 10 per cent in mains supply voltage not exceeding 0·01 per cent.

Grid Bias Supply. Adjustable from zero to 250V at 100μA maximum.

Reflector Supply. Adjustable from zero to 500V at 1mA maximum. Stability and ripple percentage as for H.T. supply.

Heater Supply. Adjustable from zero to 8V A.C., at 2A maximum.

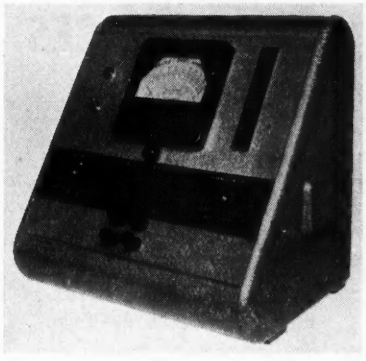


Radio Aid Ltd,
29 Market Street,
Watford,
Hertfordshire.

Electronic Multi-range Meter

(Illustrated below)

THE Clare Instrument Company's wide range linear scale ohm meters are now available with built-in ranges



for voltage and current employing a stable cathode-follower indicator system. Current ranges down to 0·3μA and voltage ranges up to 30kV at 3·3MΩ/V full-scale can be provided. A typical instrument would cover resistance ranges from 3Ω to 1 000MΩ, current from 0·3μA to 300mA D.C. and voltage from 3V to 300V D.C., F.S.D. Additional A.C. and D.C. ranges can be supplied to order.

Clare Instrument Co,
Rickmansworth,
Herts.

100db Step Attenuator

THE TF1073 is a 75Ω R.F. attenuator variable in 1db steps from 0 to 100db. Using the full 100db at 100Mc/s the maximum error does not exceed 0·6db. It consists of two sections in cascade, the first has an attenuation range of 80db in 20db steps and the second has a range of 20db in 1db steps. Input power up to a maximum of 0·25W may be applied to the attenuator (approx 4V R.M.S. at 75Ω).

The complete unit is housed in a metal case measuring 11in high by 7$\frac{1}{2}$in wide by 7in deep.

Marconi Instruments Ltd,
Longacres,
St. Albans,
Hertfordshire.

BOOK REVIEWS

The Present State of Physics

Edited by Frederick S. Brackett. 265 pp. 60 figs. Demy 8vo. American Association for the Advancement of Science. 1954. Price $5.

THIS volume embodies a symposium presented on 30 December 1949 at the New York meeting of the American Association for the Advancement of Science. Despite its title—though understandably—it deals with only a selection of recent developments in four main subjects; those of elementary particles, physics of the solid state, chemical physics and biophysics. Any writer under such a broad title has to choose the extent to which he will sacrifice thoroughness to comprehensiveness. Most of the present authors have evidently decided in favour of the thorough discussion of relatively narrow but typical problems, though J. C. Street's paper on Developments in Cosmic Radiation, 1945-1950 and Karl Lark-Horowitz's on The New topics, some of course pre-dating by many years the current spate of papers on germanium.

From a relatively brief but excellent historical survey covering the initial discoveries of non-metallic conduction, Hall effect, thermoelectric effects, contact rectification, and photoelectric effects, the author proceeds to a highly detailed discussion of the electrical properties of germanium in bulk form. A clear account is given of the effect of chemical impurities and lattice defects, and of current methods of producing these to a controlled extent. A good deal of space is devoted to theoretical attempts to correlate experimental findings, but the tentative and exploratory nature of some of the theory is made clear even to an outsider.

J. Bardeen follows with a lucid discussion of the flow of electrons and "holes" in semiconductors. Designers of transistor circuits will find much of value here, particularly towards an appreciation of the limitations of transistors. Holes in n-type germanium, for example, are reported to have lifetimes sometimes as long as 1 000μsec. Hole mobility in germanium, 1 700cm/sec per volt/cm, is roughly half that of electrons, and mobilities of both holes and electrons in most other semiconductors are lower. The fundamental limitations on the frequency response of transistors are thus very different from those on thermionic devices.

The paper by von Hippel on barium titanate ferroelectrics is refreshingly written and exciting in its implications. Only three groups of substances are so far known to show electrical remanence effects analogous to those of ferromagnetism, and of these only barium titanate offers interesting properties in an easily processed material over a suitable temperature range. Relative dielectric constants (ϵ'/ϵ_o) as high as 10 000 have been observed near the critical temperature (about 120°C). The value of ϵ'/ϵ_o depends strongly on temperature and applied D.C. field strength, dropping by a factor of 5 over the ranges 120-20°C and 0-2·5MV/m. Technical applications of these properties are mentioned but not discussed.

In the section on elementary particles, P. Kusch reports the first evidence for the theoretical prediction that an electron interacting with a quantized radiation field should show a magnetic moment higher (by $1/(2\pi \times 137)$) than that predicted from Dirac's classical theory neglecting the interaction. An accuracy better than 1 part in 10^6 is claimed for the atomic-hydrogen-beam resonance measurements from which the calculations were made. Edward P. Ney and J. C. Street in two papers on cosmic radiation give a clear picture of progress in this fertile breeding-ground of new elementary particles.

The sections on chemical physics and biophysics are interesting if only to show how wide a range of topics now comes under the name of physics. The contributions range from P. J. W. Debye's on the Structure of Polymers and Lumry and Eyring's on Chemical Kinetics of Biological Systems, to those of F. Brink, Jr., on Conduction of Nerve Impulses and F. H. Johnson on Bioluminescence.

The reader may be intrigued by an arresting contrast in tone between the second and third of these papers. Lumry and Eyring begin: "A conceptual basis for the understanding of the living organism is probably complete at the present time". Brink concludes his review of the neurophysiologist's theoretical goal by remarking more modestly, "We are far from this desirable state of affairs". There is, of course, no necessary contradiction between the two statements . . . Both papers contain most illuminating information on the properties of the nerve fibre as a communication channel.

The volume, as a whole, is well produced and remarkably free from misprints. It contains a useful if rather slender index. In the circumstances of its origin one can scarcely complain of omissions, but the mention of bioluminescence draws attention to the absence of electroluminescence from the topics covered in the solid state symposium. These and other omissions would be a blemish in any volume having this title if written by a single author. But as a stimulating selection from current work, the present symposium is well worth reading.

D. M. MACKAY.

CATHODE RAY TUBE TRACES

By H. Moss, Ph.D.

Price 10/6

(Postage 6d.)

This monograph is based on a series of articles published in Electronic Engineering and contains in addition, the elementary theory of common types of traces with notes on their production.

Order your copy through your bookseller or direct from

Electronic Engineering

28 ESSEX STREET, STRAND, W.C.2

Electronics in particular combine breadth of purview with considerable detail of treatment. The book should therefore be read more as an authoritative and representative sample than as a balanced general report of current progress in physics.

Undoubtedly of greatest interest to most readers of this journal will be the three papers on physics of the solid state, which deal almost exclusively with semi-conductors and ferroelectrics. Lark-Horowitz's painstaking survey already mentioned occupies 71 pages and provides no fewer than 352 references to the literature on semiconductors and related

Electronics

By A. T. Starr. 395 pp., 64 figs. Demy 8vo. Sir Isaac Pitman & Sons Ltd. 1954. Price 32s. 6d.

THIS book is one of the engineering degrees series produced by the publishers and was specially written to cover the syllabus for the subject of electronics in the University of London.

The field of electronics is now so large and varied that it is obviously impossible to cover it all thoroughly in a book of this size and price. That it is done so well indicates the familiarity of the author with his subject and his economy of words and skill in technical writing.

Chapter I deals with physical fundamentals in a most interesting way, emphasizing wave mechanics and the quantum theory as explaining more completely the behaviour of matter than the classical and simple picture of the electrons revolving round the nucleus like planets around the sun. The author is therefore able to bring into this chapter the conditions for thermionic emission, cathode ray tubes, photo electric emission, contact potential, and, of great interest now, the behaviour of semi-conductors. The operation of transistors and their main characteristics are neatly covered.

Chapters II and III are devoted to thermionic valves of many types and include cathode ray tubes and camera tubes. Rectifiers and rectification circuits are particularly well described. Sometimes valves are referred to as tubes and it is a pity that a uniform style of drawing is not adopted throughout the book. In many places "envelopes" are not included around the electrodes and some circuit diagrams are thus made more difficult to understand.

Chapter IV covers circuit theory starting with some of the theorems, laws, transformations and networks. Steady state conditions, unit step and impulse functions are then treated. Filters are particularly well covered as would be expected from the author.

Amplifiers, oscillators and detectors are described in Chapter V. Positive and negative feedback is discussed and the effects of each. Multivibrators and timebase circuits are also covered. Waveforms at the various parts of the circuits are shown in most cases and this is always a help to the understanding of circuit behaviour.

Electronic applications are shown in Chapter VI. Servo mechanisms and motor controlled equipment are described in some detail and a number of devices used commercially such as welder control circuit, dielectric heating, and fluorescent lighting. A circuit and description of a photographic timer is included but the circuit has a resistor missing and another incorrectly connected and could not work in the form shown. The circuit was described by the reviewer in the March, 1950, issue of ELECTRONIC ENGINEERING.

The book finishes with several appendices, mainly of a mathematical nature such as theorems and functions, steady state A.C. theory including complex numbers and vectors and passes on to Fourier analysis, and impulse and unit step functions.

The appendix concludes with operational calculus forms due to Heaviside and Laplace and the relation between them, the M.K.S. system, and a useful summary of noise in circuits.

The book has a great number of questions and answers throughout and considering the enormous field it covers does so in a most workmanlike way.

C. H. BANTHORPE.

Power System Transients

Edited by E. Openshaw Taylor. 176 pp., 70 figs. Demy 8vo. George Newnes Ltd. 1954. Price 21s.

THIS symposium, based on a series of lectures delivered at the Electrical Engineering Department of the Heriot-Watt College, Edinburgh, brings together in a convenient form the latest available information on the various aspects of the subject.

Power system engineers, transmission engineers and designers of transformers, switchgear and protective gear will find this work useful for purposes of reference. Students intending to specialize in electrical machinery design, power generation or transmission and distribution will find the book provides a valuable complement to their standard textbooks.

A Text Book of Radar

Edited by E. G. Bowen. 617 pp., 300 figs. Royal 8vo. 2nd Edition. Cambridge University Press. 1954. Price 45s.

THE authors of this book, which was first published in 1947, are members of the staff of the Radiophysics Laboratory in Australia and the main emphasis of the book is on the work done there. At the same time a very balanced account is given of the British and American work and the result is a comprehensive survey of radar techniques.

The main portion of the book, consisting of an introductory chapter, one on the fundamental principles of radar operation and a number, each dealing with a particular component of a radar system, have been revised from the first edition. These chapters are each written by the radiophysics laboratory worker, specifically responsible for the component being discussed, so that the book is unquestionably an authoritative one. The level of the treatment is, however, somewhat variable, ranging from the section on cavity resonators, which is suitable for a student, to that on transmission line technique, which is more appropriate to someone already working in this field. On the whole, the second approach predominates and the principal value of the book is as a general reference for those working on radar design.

The concluding chapters, which have been completely rewritten, integrate the remainder by discussing complete radar systems. Military radars are discussed historically and the way in which the development progressed up to the end of the late war is concisely covered. The peace time uses of radar as an aid to air and marine navigation have led to the development of other types of system and these are also discussed. The final chapter is a most interesting one, in which an account is given of the advances resulting from the application of radar techniques to fundamental research. The topics discussed in this chapter include microwave spectroscopy, radio astronomy and linear accelerators.

J. BROWN.

Television Engineers' Pocket Book

Edited by E. Molloy and J. P. Hawker. 228 pp., 80 figs. George Newnes Ltd. 1954. Price 10s. 6d.

THIS book has been specially prepared to meet the growing needs of engineers, dealers, servicemen and television enthusiasts for a handy compendium of practical information and technical data. In addition to useful reference information on cathode-ray tubes, valves, and the leading particulars of more than 300 popular models, the book contains valuable guidance on installing, servicing and aligning receivers.

Practical Television Circuits

By F. J. Camm. 288 pp., 156 figs. Demy 8vo. George Newnes Ltd. 1954. Price 15s.

THIS book gives constructional details, with wiring diagrams, of a number of television receivers which have been described in *Practical Television*.

The contents also include details and diagrams for a spot wobbler, a black spotter, E.H.T. generators, a pattern generator, preamplifiers, etc.

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Electron Optics

By O. Klemperer. 471 pp., 120 figs. Demy 8vo. 2nd Edition. Cambridge University Press, 1953. Price 50s.

AMONG the many good textbooks on electron optics this work, perhaps more than any other, bears the individual stamp of its author, a distinguished electron physicist of 28 years' standing, with almost equally long industrial as academic experience. His own work has a deservedly prominent place in almost every chapter, and much of the mass of useful data collected in this book is the result of his own indefatigable researches.

The science and technique of electron optics has now grown to such an unmanageable size, that a book like the present, of 437 text pages cannot give even comprehensive abstracts of the majority of the important papers, but has to refer to them often in a few lines only. The research worker who wants to consult this book with a view to learning something in his own special field, must be content with finding in it an unusually complete enumeration of the points at which special fields of research branch off the main body of electron optics. In almost all cases he will have to complete his study by referring to the original publications. This cannot be helped, else the book would have become an encyclopedia.

Dr. Klemperer's book can be compared to a road map, in which all the highways are traced, and all cross roads are neatly and completely labelled with signposts, without tracing all the way the second and third class roads. This is what gives the work its special and useful character, even at this late hour when it has to compete with so many other textbooks. Compared for instance with Walter Glaser's Elektronenoptik, which is almost twice its size and four times its price, this book gives only a cursory introduction to theoretical electron optics, but it opens up many times more vistas into practical applications.

Some of the chapters deserve special mention, such as those on space charge, on emission systems, and on line focus systems, as in these fields the author's own work, published here for the first time in many instances, is of first class importance.

The first two chapters deal briefly with the fundamentals of electron optics and with the cardinal points of electron lenses. The third chapter is a comprehensive and very useful survey of almost all practical ray tracing methods. Chapters IV and V contain in a condensed form much useful reference material on the cardinal data of electric and magnetic lenses. Chapter VI, on the geometrical aberrations, represents a brave attempt to condense into 48 pages a subject of extraordinary intricacy and complexity. The next chapter which bears the somewhat unusual title "Electronic Aberrations" is chiefly devoted to the chromatic aberrations, their avoidance in lenses and their utilisation in spectrometers. The last is a subject in which the author is a pioneer; it was he who devised, in 1933, the first lens spectrometer. The diffraction errors receive only cursory treatment. Chapters IX and X, on emission systems and on line focus systems will be of special value to the designer. This too is a field in which the author's contributions are among the most important. The chapter on deflecting fields, which includes spectrometers as well as television tubes is of the "first-class highways and signposts" type, while the last chapter on the applications of electron optics in industry and research consists mainly of signposts. This last is a field in which there is no highway; it is still more or less free for the inventive imagination which does not run on rails.

It would be unkind to point out the few errors, and the few omissions of important references in a book which represents such an enormous amount of careful work, and which contains about 600 bibliographic entries, all digested.

The readers to whom this book will be useful and even indispensable are in the first line all electronic engineers and physicists engaged in research or development, and those students who do not only want to pass their examinations, but wish to prepare themselves seriously for a career in electronics.

D. GABOR.

Transistoren—Wirkungsweise, Eigenschaften und Anwendungen (Transistors—Mode of Action, Properties and Applications)

By M. J. O. Strutt. 166 pp., 121 figs. Demy 8vo. S. Hirzel Verlag, Zurich. 1954. Price S.Fr.21.

THE book deals systematically with the theory of the semiconductor triodes. In an introductory chapter the author explains what is understood by a transistor, gives the characteristics of a point transistor and compares them with those of a passive impedance quadrupole. Equivalent diagrams of a point transistor are developed by simple matrix algebra and practical values are given for the impedances. The power gain is calculated and the three different quadrupole connexions of the transistor are discussed depending on which two of the three electrodes, emitter, collector or base, are used as common input and output electrodes. Stability questions are briefly dealt with.

The next chapter is devoted to the electronics of materials. After a brief reference to the movement of slow electrons the electrons within atoms are discussed on the basis of the quantum theory and the periodical system of elements. The wave nature of the electron is mentioned and various cases of diffraction and reflexion are illustrated and calculated. Dealing with electrons in solids and with their energy levels the author shows the difference between conductors, semiconductors and insulators and particularly explains the behaviour of n-semiconductors containing "donors" and p-semiconductors containing "acceptors." Formulae are given for the quantitative investigation of these relations.

The third chapter deals with what is called contact electronics. The contact between different metals, between metals and n- and p-semiconductors and between different semiconductors is discussed as well as the rectification at contacts. Here the actions of barrier layers is explained.

After these more general explanations the fourth chapter shows their application to point transistors. Their effective resistances and current amplification at the collector electrode are calculated. The improvement gained by activation is discussed and an estimate is made of transition times, capacitances and inductances. A short section deals with noise questions and finally the point transistor using a p-semiconductor is treated.

The fifth chapter is devoted to junction transistors of the n-p-n type and other kinds and to their current amplification. Fieldistors and photo-transistors are explained.

The sixth chapter shows how the duality principle and the analogy principle may be used to explain the behaviour of transistors in comparison with vacuum tubes.

In the seventh, eighth and ninth chapters the use of transistors in input stages, output stages and as oscillators are discussed. For the input stages special consideration is given to noise values and it is stated that these have now been reduced to 2db. Limiting frequency and distortion are discussed at some length. Connexions for the output stages are first dealt with using idealized characteristics and comparisons are made with the behaviour of vacuum valves. Then the efficiency and distortion with non-idealized characteristics are discussed. Various connexions are shown for oscillator circuits, the production of negative resistances and their application for the generation of relaxation oscillations are discussed about which quite an extensive literature exists.

The final chapter deals with measuring methods and results of measurements referring to semiconductors in general and to transistors in particular. It should be noted that the "life" of the electron as here defined, i.e. the time taken for the recombination of an electron and a hole, must not be confounded with the life of the transistor, the former amounting to some 100 μsec while the latter has been stated to be about 8 000h or even up to 100 000h. Some block diagrams show how the characteristics of transistors may be taken on cathode ray oscillographs and how noise values may be measured.

A bibliography of 148 items to which reference is made at the end of each section is given and covers the literature to about the middle of 1953. A combined subject and name index concludes the book which is well produced. It contains much useful information in a concise manner and should be on the shelves of every laboratory dealing with transistors. As its price is moderate, students and research workers in this and neighbouring fields will be well advised to possess the book.

R. NEUMANN.

The Practical Electrician's Pocket Book 1955

Edited by R. C. Norris. 550 pp. Demy 16mo. 57th Edition. Odhams Press Ltd. 1954. Price 5s.

THIS edition contains several new and extended chapters on electrical plan for homes, apprenticeship in the electrical contracting industry, illuminated signs and floodlighting, electrical equipment for catering, electricity in agriculture and horticulture, etc. This reference book should prove of interest.

Short News Items

Sir Anthony Eden, the Foreign Secretary, is to be the guest of honour at the annual dinner of the Radio Industry Council at the Dorchester Hotel, London, on 1 December. Lord Burghley, president of the Radio Industry Council, will preside.

The Fulmer Research Institute held an open day on 2 November when His Royal Highness the Duke of Edinburgh opened the new engineering laboratory. The Institute was founded in 1946 by the late Colonel W. C. Devereux. One of its principal aims is to bring research facilities within the means of firms which themselves are unable to maintain a full-time research laboratory. The opening of the new engineering laboratory marks another stage in the development and expansion of the Institute.

The Physical Society's autumn meeting will be held in the Poynting Physics Building, The University, Edgbaston, Birmingham, on 13 and 14 December. The subject of the meeting, which is being organized by Professor R. E. Peierls will be "A Survey of Field Theory". The meeting will consist of a series of lectures which will attempt to describe the present knowledge of the interactions between mesons, nucleons, photons and electrons, without assuming specialist knowledge. Non-members are welcome to attend this meeting and application forms may be obtained from the Physical Society, 1 Lowther Gardens, Prince Consort Road, London, S.W.7.

The Leicester firm of Taylor, Taylor & Hobson Ltd have inaugurated a new factory-to-buyer delivery service by van direct to their customers in Western Germany, Italy, France, Holland, Belgium and Switzerland. The first delivery was an electronic measuring instrument for one of Germany's largest manufacturers of ball bearings.

The 1955 Physical Society Exhibition of Scientific Instruments and Apparatus will be held in the New Hall of the Royal Horticultural Society, Westminster, from Monday, 25 April, to Thursday, 28 April. It is anticipated that about 140 exhibitors will take part. The change of venue from Imperial College to the Royal Horticultural Society's New Hall will in no way change the unique character and well-known purpose of the exhibition.

The London Electric Wire Company and Smiths Ltd, and its Associates, have removed their Birmingham branch to new and larger premises. Their address is Lewcos House, 119/120 Moseley Street, Birmingham 12. Telephone: Victoria 3731/4.

Her Majesty the Queen has been graciously pleased to approve a recommendation made by the Council of the Royal Society for the award of the Royal Medal for the current year to Sir John Cockcroft, K.C.B., C.B.E., F.R.S., for his distinguished work on nuclear and atomic physics.

The President and Council of the Royal Society have awarded the Hughes Medal to Mr. M. Ryle, F.R.S., for his distinguished and original experimental researches in radio astronomy.

The Board of Associated Electrical Industries Ltd have reorganized the AEI Companies into four groups: BTH Group, Ediswan-Hotpoint Group, M-VE Group and Overseas Group. The chairman of AEI has become chairman of each of the groups. The following are the group managing directors: BTH Group, Mr. E. H. Ball; Ediswan-Hotpoint Group, Mr. A. N. E. McHaffie; M-VE Group, Dr. C. Dannatt; Overseas Group, Dr. I. R. Cox. The group managing directors are members of the AEI Board and form, with the chairman, the Executive Committee of the Board.

Redifon Ltd announce that two 650 ton trawlers now being built in a German shipyard for the Standard Steam Fishing Co Ltd of Grimsby, and an associated company, are to be fitted with Redifon marine radio equipment. In addition, Redifon will supply V.H.F. radio and inter-communication equipment.

BINDING OF VOLUMES

Arrangements for the binding service are being continued this year, and the 1954 volume can be bound at an inclusive charge of £1.

Copies will be bound, complete with index and with advertising pages removed, in a good quality red cloth covered case blocked in gold on the spine.

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The Index for Volume XXVI (1954) free.

The Eighth Canadian International Trade Fair, sponsored by the Canadian Government, will be held in Toronto from 30 May to 10 June 1955.

The New Marconi College at Chelmsford, Essex, has recently been completed and provides facilities for technological training for nearly 100 students and residential accommodation for 50. The majority of the students are already university graduates and, in the case of British students, they are mainly employees of the company; the courses being designed to enable them to play a useful part in the company's research and development departments. Most of the overseas students are sent by their governments or by customers of the company, frequently for training on specific equipments.

A Television Receiver Intermediate Frequency of 34·65Mc/s with a high oscillator has been recommended in a recent report issued by the British Radio Manufacturers' Association. In this report, comprehensive reasons and arguments leading to the recommendation of this frequency are given; these are based mainly upon interference received from various sources and interference to other services caused by radiation from the local oscillator of the receiver. This report has received general endorsement by members of B.R.E.M.A., and has the approval of the G.P.O.

Pye/Technograph Agreement. It has been announced that Pye Ltd of Cambridge have acquired an interest in Technograph (Printed Circuits) Ltd, who hold patents for printed circuits all over the world. Mr. H. Vezey Strong, chairman of Technograph, who made this announcement recently, stated that it was the intention of both companies to work closely in touch with each other in furthering the development and application of printed circuits, not only in this country but also through their organizations all over the world.

The General Electric Co Ltd announce that they have recently equipped the Coryton Oil Refinery, owned by the Vacuum Oil Co Ltd, with a comprehensive V.H.F. radio installation. This provides two-way communication between the vehicles and a control station at transport headquarters.

Ferranti and Powers-Samas announce that they have agreed to collaborate in the development, production and marketing of electronic data processing equipment.

Meetings this Month

THE BRITISH INSTITUTION OF RADIO ENGINEERS

Date: 29 December. Time: 6.30 p.m.
Held at: The London School of Hygiene and Tropical Medicine, Keppel Street, Gower Street, London.
Discussion: Education and Training of Radio Engineers.

Merseyside Section

Date: 2 December. Time: 7 p.m.
Held at: The College of Technology, Byron Street, Liverpool 3.
Lecture: Electronics in Materials Handling.
By: L. Landon Goodman.

Scottish Section

Date: 2 December. Time: 7 p.m.
Held at: The Institution of Engineers and Shipbuilders, Elmbank Crescent, Glasgow.
Lecture: Some Interesting Applications of Electronics to Photography.
By: D. M. Neale.

North Eastern Section

Date: 8 December. Time: 6 p.m.
Held at: Neville Hall, Westgate Road, Newcastle-upon-Tyne.
Lecture: Logic, Algebra and Relays.
By: Emrys Williams.

West Midlands Section

Date: 8 December. Time: 7.15 p.m.
Held at: Wolverhampton and Staffordshire Technical College, Wulfruna Street, Wolverhampton.
Lecture: Industrial Applications of Electronic Control.
By: J. A. Sargrove.

THE BRITISH KINEMATOGRAPH SOCIETY

Date: 15 December. Time: 7.15 p.m.
Held at: The Gaumont British Theatre, Film House, Wardour Street, London, W.1.
Lecture: Optical Developments Concerning Anamorphic Lens Systems.
By: G. H. Cook.

THE INSTITUTE OF NAVIGATION

Date: 17 December. Time: 5 p.m.
Held at: The Royal Geographical Society, 1 Kensington Gore, London, S.W.7.
Lecture: The Accuracy of Dead Reckoning in Air Navigation.
By: C. S. Durst.

THE INSTITUTE OF PHYSICS

Date: 15 December. Time: 6.30 p.m.
Held at: The Institute's House, 47 Belgrave Square, London, S.W.1.
Lecture: Photoelectric Measurement of Polarized Light.
By: A. M. Taylor.

THE INSTITUTION OF ELECTRICAL ENGINEERS

All London meetings, unless otherwise stated, will be held at the Institution, commencing at 5.30 p.m.

Radio Section

Date: 1 December.
Lecture: The Vertical Radiation Patterns of Medium-Wave Broadcasting Aerials.
By: H. Page and G. D. Monteath.
Date: 13 December.
Discussion: Practical and Economic Problems in the Maintenance of Domestic Television Receivers.
Opened by: W. L. Greenwood.

Informal Meeting

Date: 6 December.
Discussion: The Applications and Limitations of Electronic and other Computors.
Opened by: L. G. Brazier.

Measurements Section

Date: 14 December.
Lectures: An Attracted-Disc Absolute Voltmeter.
By: G. W. Bowdler.
The use of an Electron Velocity Analyzer to stabilize a 50kV D.C. Voltage source to a few parts in a million.
By: M. E. Haine and M. W. Jervis.
A Precision Direct-Current Stabilizer.
By: M. W. Jervis.

Supply Section

Date: 15 December.
Lecture: Short-Circuit Forces on Turbo-Alternator End Windings.
By: J. B. Young and D. H. Tompsett.

East Midland Centre

Date: 16 December. Time: 6.30 p.m.
Held at: The Albert Hall, Nottingham.
Faraday Lecture: Courier to Carrier in Communications.
By: T. B. D. Terroni.

Cambridge Radio Group

Date: 7 December. Time: 6 p.m.
Held at: Cambridgeshire Technical College.
Lecture: Transistor Circuits.
By: E. H. Cooke-Yarborough.

Mersey and North Wales Centre

Date: 6 December. Time: 6.45 p.m.
Held at: The Philharmonic Hall, Liverpool.
Faraday Lecture: Courier to Carrier in Communications.
By: T. B. D. Terroni.

Tees-Side Sub-Centre

Date: 1 December. Time: 6.30 p.m.
Held at: The Cleveland Scientific and Technical Institution, Middlesbrough.
Lecture: Fluorescent Discharge-Tube Circuits and Operating Problems.
By: J. Cates.

Northern Ireland Centre

Date: 14 December. Time: 6.30 p.m.
Held at: The Engineering Department, Queen's University, Belfast.
Lecture: The Possibilities of a Cross-Channel Power Link between the British and French Supply Systems.
By: D. P. Sayers, M. E. Laborde and F. J. Lane.

South-East Scotland Sub-Centre

Date: 7 December. Time: 7 p.m.
Held at: The Carlton Hotel, North Bridge, Edinburgh.
Lecture: Technical Arrangements for the Sound and Television Broadcasts of the Coronation Ceremonies on 2 June, 1953.
By: W. S. Proctor, M. J. L. Pulling and F. Williams.

South-West Scotland Sub-Centre

Date: 15 December. Time: 7 p.m.
Held at: The Institution of Engineers and Shipbuilders, 39 Elmbank Crescent, Glasgow.
Lecture: Servo Machines.
By: W. S. Wood.

South Midland Centre

Date: 6 December. Time: 6 p.m.
Held at: The James Watt Memorial Institute, Great Charles Street, Birmingham.
Lecture: Technical Arrangements for the Sound and Television Broadcasts of the Coronation Ceremonies on 2 June, 1953.
(Joint meeting with the South Midland Radio Group, and Supply and Utilization Group).

Rugby Sub-Centre

Date: 10 December. Time: 7 p.m.
Held at: The Temp'e Speech Room, Rugby.
Faraday Lecture: Courier to Carrier in Communications.
By: T. B. D. Terroni.

Southern Centre

Date: 1 December. Time: 6.30 p.m.
Held at: The College of Technology, Portsmouth.
Lecture: The Possibilities of a Cross-Channel Power Link between the British and French Supply Systems.
By: D. P. Sayers, M. E. Laborde and F. J. Lane.

Western Centre

Date: 13 December. Time: 6 p.m.
Held at: The South Western Electricity Board Offices, Colston Avenue, Bristol.
Repeat of Lecture given at Southern Centre.

RADIO SOCIETY OF GREAT BRITAIN

Date: 17 December. Time: 6.30 p.m.
Held at: The Institution of Electrical Engineers, Savoy Place, London, W.C.2.
Annual General Meeting.

THE TELEVISION SOCIETY

Date: 10 December. Time: 7 p.m.
Held at: 164 Shaftesbury Avenue, London, W.C.2.
Lecture: Television Circuit Refinements.
By: C. H. Banthorpe.

PUBLICATIONS RECEIVED

WIRELESS WORLD DIARY 1955. This diary is now in its 37th year of publication. It includes data for the forthcoming commercial television transmissions and the proposed V.H.F. sound broadcasts. Iliffe & Sons Ltd., Dorset House, Stamford Street, London, S.E.1. Price 5s. 10d. (leather), 4s. 1d. (rexine).

CIRCUITS ELECTRONIQUES by J. P. Oehmichen is a well presented book of considerable interest to those concerned with the subject of electronic circuits. Societe des editions Radio, 9 Rue Jacob, Paris, 6. Price Fr. 1320.

MASS SPECTROMETRY by A. J. B. Robertson is a monograph in the Methuen series which attempt to give brief but authoritative accounts of the present state of knowledge in various departments of Chemistry. Methuen & Co. Ltd., London. Price 8s. 6d.

THE ZERO READER FLIGHT DIRECTOR, SPERRY GYROPILOTS, AIR DRIVEN HORIZON TYPE HL8 FOR AEROBATIC AIRCRAFT, AERONAUTICAL EQUIPMENT, DUPLEX FLIGHT DATA SYSTEM, A GYRO-MAGNETIC COMPASS FOR AIRCRAFT, ELECTRIC GYRO HORIZONS, and THE ZERO READER FLIGHT DIRECTOR TYPE ZL1 are the subjects of recent brochures produced by the Sperry Gyroscope Co. Ltd., Great West Road, Brentford, Middlesex.

BSI ANNUAL REPORT 1953-54 runs to a total of 200 pages and provides almost at a glance an impression of the very comprehensive range of industries which use the BSI facilities to prepare agreed standards for their products and services. British Standards Institution, British Standards House, 2 Park Street, London, W.1. Price 5s.

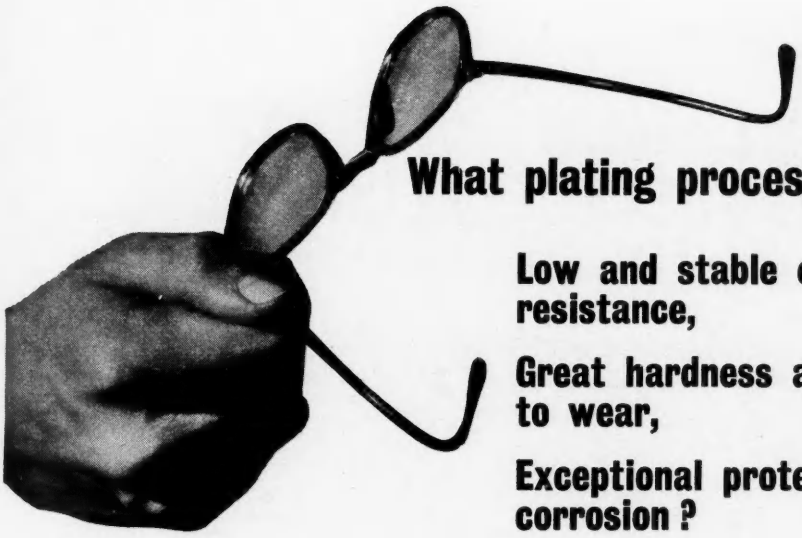
TELEVISION CIRCUIT REFINEMENTS is a book by C. H. Banthorpe explaining the purpose and operation of old and new circuit developments used to improve the performance, reliability or safety of commercial television receivers. Norman Price (Publishers) Ltd., 283 City Road, London, E.C.1. Price 5s.

VADE MECUM 1954 is the 11th edition of this comprehensive valve guide. Valves are tabulated in alphabetical and numerical order. P. H. Brans Ltd., Antwerp. Price 25s.

INDUSTRIAL ENGINEERING is the subject of the last of the reports of the series of British Productivity teams that have visited America. The main body of the report contains chapters on the techniques and functions which either come within the scope of industrial engineering or closely affect its practice, followed by others on human factors with which the industrial engineer is vitally concerned. The Anglo-American Council on Productivity, 21 Tothill Street, London, S.W.1. Price 5s.

RADIOLOCATOR IV is a brochure which provides, in pictorial form, an explanation of the controls and switch selection applicable to the Marconi Marine Radiolocator IV radar equipment. It should enable personnel to operate the apparatus with the minimum of reference to the more detailed technical instruction manual supplied with the installation. The Marconi International Marine Communication Co., Ltd., Chelmsford.

TRUVOX RADIO JACK leaflet describes a unique unit for use with a tape recorder which is designed to give direct reception from either of two local stations or to make recordings, for future playback, of any of the programmes radiated by the selected stations. Copies are available from Truvox Ltd., 15 Lyon Road, Harrow, Middlesex.



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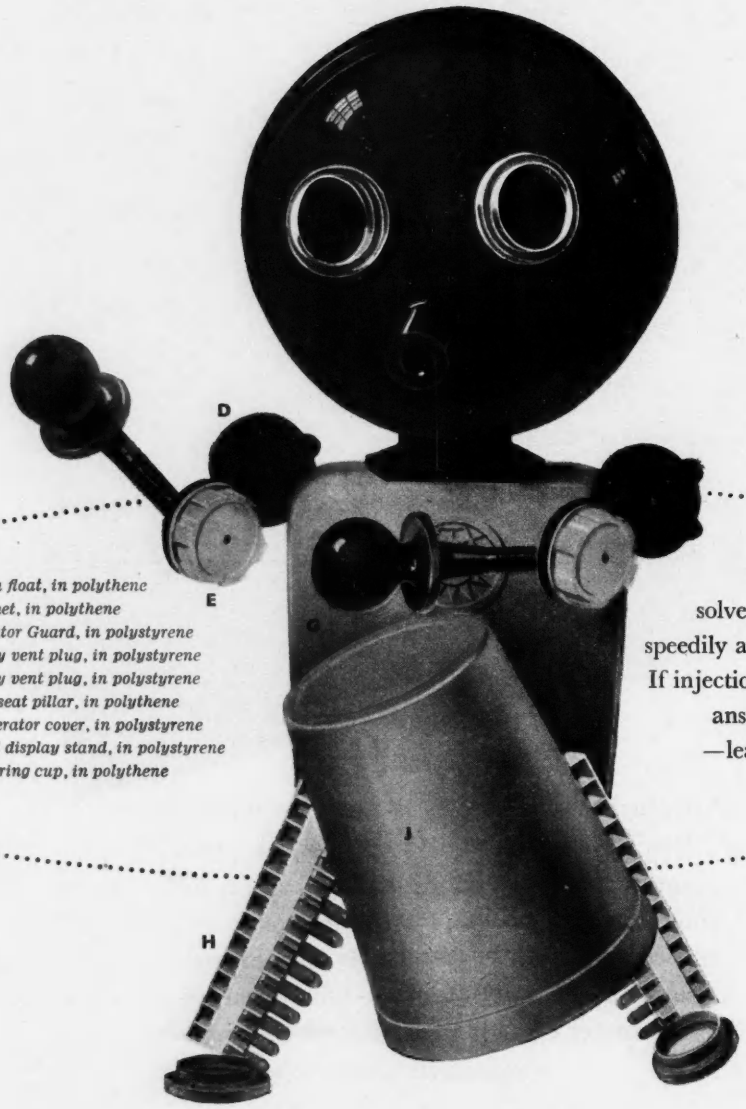


A *Cistern float, in polythene*
B *Grommet, in polythene*
C *Separator Guard, in polystyrene*
D *Battery vent plug, in polystyrene*
E *Battery vent plug, in polystyrene*
F *Toilet seat pillar, in polythene*
G *Refrigerator cover, in polystyrene*
H *Dental display stand, in polystyrene*
J *Measuring cup, in polythene*

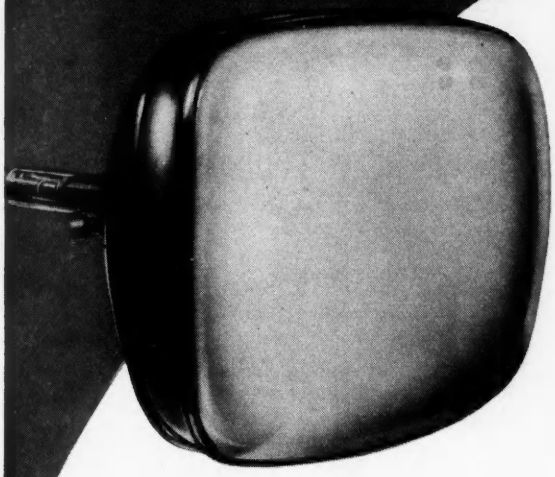
Lorival designers solve plastic problems speedily and economically. If injection mouldings can answer *your* problem —leave it to Lorival!

LORIVAL PLASTICS

L.54

UNITED EBONITE & LORIVAL LTD., LITTLE LEVER, NR. BOLTON, LANCS

ALUMINIZED

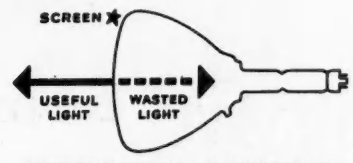


60% brighter pictures more contrast extra tube life

AN Ediswan Mazda aluminized picture tube gives a picture 60% brighter and more contrasty than is possible with an ordinary tube.

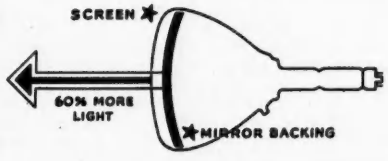
In addition, Ediswan aluminizing protects the screen from ion burn and, with the new Ediswan ion trap tetrode gun to protect the cathode, tube life is increased.

Ediswan production methods, which include the special in-line vacuumizing system, ensure a higher, more uniform standard of lasting efficiency. For complete satisfaction demonstrate and recommend Ediswan Mazda aluminized picture tubes.



WITHOUT ALUMINIZING

Without aluminizing, tubes waste half their light (see diagram above). To counteract this the brilliance must be increased and the tube life is shortened.



WITH EDISWAN ALUMINIZING

Ediswan aluminized tubes have a mirror backing to the screen. All the light is thus thrown forwards giving brighter, clearer pictures and extra life.

RV9

EDISWAN
MAZDA
ALUMINIZED CATHODE RAY TUBES

THE EDISON SWAN ELECTRIC COMPANY LIMITED,
155 Charing Cross Road, London, W.C.2 and Branches.
Member of the A.E.I. Group of Companies.

NATION WIDE SERVICE

6 fully equipped cathode ray tube service depots provide better, quicker tube testing should the need arise. Stocks of tubes are available in 26 Ediswan Offices. Only Ediswan give such complete backing to the Trade.

Photograph by courtesy of Handley Page Ltd.

PRE-FLIGHT TESTS with GOODMANS VIBRATORS

The flight characteristics of a newly designed aeroplane are the subject of lengthy calculations before the first prototype is built. Whilst the mathematical calculations are themselves accurate, they are based, as in all design work, on several assumptions which have to be verified by a series of pre-flight tests.

One of these essential investigations is the Ground Resonance test, the purpose of which is to determine the various complex modes of vibration of the airframe structure. The frequency of the mode and the dynamic response at remote parts of the aircraft must be accurately determined. The information obtained together with the aerodynamic derivatives is used in predicting the critical ' flutter ' speed of the aircraft. The illustration shows one of the two Goodmans Model 8/600 Vibration Generators which were used to excite the Handley Page " Victor " for this very important test.

For wide frequency range vibration testing and dynamic response investigations, Goodmans Vibration Generators are an obvious choice. These units require no field excitation and provide a faithful reproduction of the input wave form. Industrial applications of controlled vibration are continually increasing ; maybe it can serve you—in which case our unique experience is at your service.

The range includes models from the 8/600 *shown, developing a force of* ± 300 *lb., to the midget model, with a force of* ± 2 *lb., for optical cell research and hairspring torque testing, etc.*

Just another of the wide applications of Goodmans Vibration Generators. Full technical data available from Vibration Division E.

GOODMANS INDUSTRIES LIMITED, Axiom Works · Wembley · Middx · Wembley 1200 (8 lines)
GD

ENTHOVEN *Superspeed*-

for *'SIX STAR'* soldering . . .

Careful alloying and the incorporation of special fluxes contribute to its efficiency —but the stellate 6-CHANNEL CORE —secret of faultless fluxing—places ENTHOVEN SUPERSPEED in a class by itself.

★ **Continuous stellate core has 6 channels of activated rosin flux.**

★ **Solders difficult parts uniformly and quickly.**

★ **Fastest non-corrosive, solder-and-flux combination for industry.**

★ **Activator is rendered harmless by soldering heat.**

★ **Eliminates dry and high resistance joints often caused by incorrect fluxing.**

★ **Flux residue is hard, non-conductive, non-corrosive and non-hygroscopic.**

Designed as the result of exhaustive research into the properties of all kinds of single and multiple core systems, ENTHOVEN stellate 6-CHANNEL CORE combines all the advantages of both. It comprises, in effect, six distinct flux channels—all located close to the circumference of the solder tube and all connected with the main central channel.

When the heated solder metal collapses, the flux is released—not merely from the channel nearest the heat, but from all six channels simultaneously. Hence the quick, generous flow of precisely the right amount of activated rosin flux eliminates all possibility of dry or high resistance joints. Hence the name *SUPERSPEED* for the most efficient and reliable of all cored solders.

MANUFACTURED BY

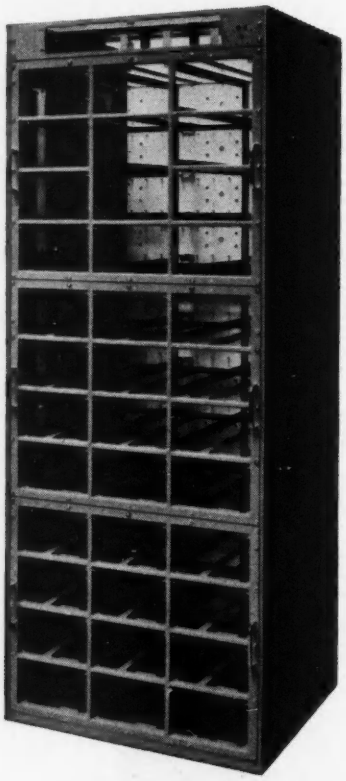
ENTHOVEN

SOLDERS LIMITED

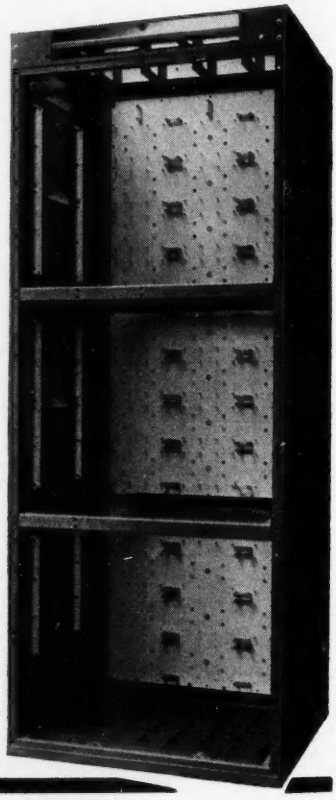
SUPERSPEED activated rosin-cored solder for general electrical, electronic and telecommunication work, and all standard uses. A.I.D. approved to M.O.S. Specification DTD 599. Complies with B.S.441, RCS 1000, and other current specifications issued by G.P.O. and other Government departments.

SUPERSPEED is available in a wide range of alloys and gauges. Samples, together with comprehensive literature, gladly sent on request.

ENTHOVEN SOLDERS LIMITED · 89 UPPER THAMES STREET · LONDON E.C.4. MANsion House 4533



You'd be as pleased as PYE!



These photographs illustrate one of the Cabinets, with Racking for miniaturised Units, which we recently produced in close co-operation with Messrs. Pye Limited of West Drayton, Middlesex,

You, too, would appreciate the fine quality of the precision metal work and welded construction; you, too, would admire the excellent finish, and—certainly—you would find us just as ready to work with your own technicians in the design and production of Cabinets and Racks to meet YOUR specialised requirements.

Send for H. & H. Catalogue of Electronic Instrument Racks, Cabinets and Cases.

Hassett & Harper Ltd

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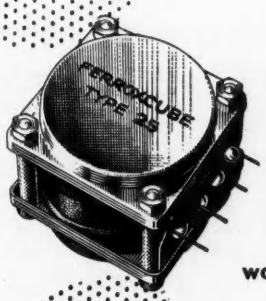
***LONDON*: 140 PARK LANE · W.1 Telephone: MAYfair 9651 (3 lines)**

CONTRACTORS TO GOVERNMENT DEPARTMENTS



High Q inductance coils

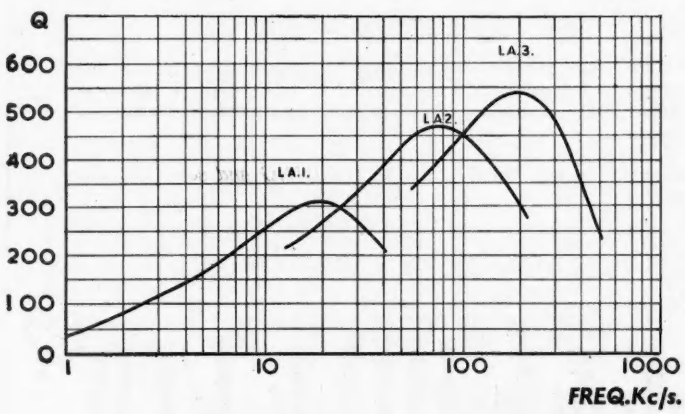
wound on Ferroxcube cores

DESIGNERS of compact and efficient tuned circuits and wave filters are making ever-increasing use of Mullard high Q inductance coils.

Based on Ferroxcube, the world's most advanced magnetic core material, these coils combine small size with an inductance of up to 30 henries over a wide frequency range. Furthermore, their convenient shape and self screening properties facilitate either individual mounting or stacking.

Full details of these and other high grade components now available from Mullard will be gladly supplied on request.

TYPICAL Q VALUES



Special Features

Small size

Low hysteresis loss factor

High value of inductance

Low self capacitance

Controllable air gap facilitating inductance adjustment

Self screening

Controlled temperature coefficient

Operation over a wide frequency range

Easily mounted

Mullard

'Ticonal' permanent magnets,
'Magnadur' ceramic magnets,
Ferroxcube magnetic cores.

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(MM450)

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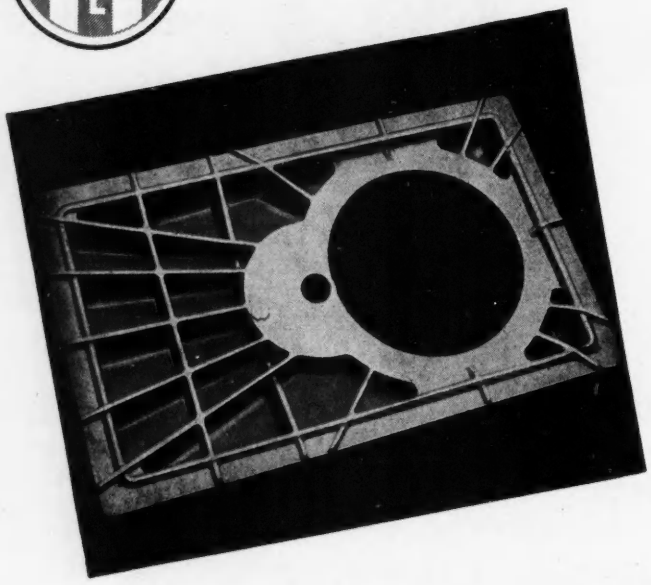

Casting in Aluminium Alloy
(approx. weight 386 lbs.)

C and L Hill LTD would welcome your enquiries for Non-Ferrous Sand Castings, Brass, Naval Brass, Brazing Metal, Gunmetal, Phosphor Bronze, Aluminium Bronze, High Tensile Manganese Bronze, High Conductivity Copper, " Hilchil " Chill Cast Phosphor Bronze Bars, Cored and Solid. Sand Castings in all Aluminium Alloy Gravity Die Castings.

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Design your Castings for SHELL MOULDING and save Machine Shop costs.

You can support the B.R.M. through the O.R.M.A. (Owen Racing Motor Association) Members £1. 1. 0 per annum. Associate Members 5/-. Car Badge (full members only) £1.10. 0 extra. Full details from : THE SECRETARY, ORMA, KENT HOUSE, MARKET PLACE, OXFORD CIRCUS, LONDON W.1. Tele : Museum 8901-6

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Both our Foundries are available for Prototype Work.

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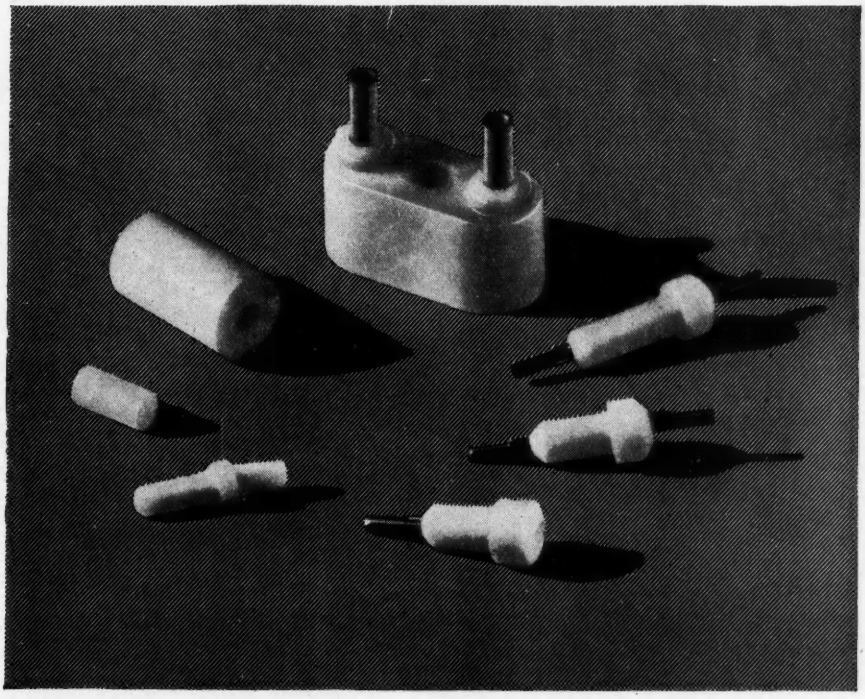
'FLUON'*

a new insulant for electronics



These very small electronic components made from 'FLUON' polytetrafluoroethylene by The Edison Swan Electric Co. Ltd., are being widely used in high grade electronic equipment where the remarkable insulating properties of 'FLUON' are essential.

Operating temperature range	— 80°C. to 250°C.
Operating frequencies	60 to 10^9 C.P.S.
Power Factor	0.0001
Dielectric Constant	2.0
Water Absorption	NIL
Non-tracking	

Can 'FLUON' solve YOUR problems?

* *'FLUON' is the registered trade mark for the polytetrafluoroethylene manufactured by I.C.I.*

Please ask for full technical data.

IMPERIAL CHEMICAL INDUSTRIES LTD., LONDON, S.W.1

P.566R

"VARIAC"

(Reg'd Trade Mark)

INFINITELY VARIABLE

auto transformers

The "VARIAC" is the original, continuously adjustable auto-transformer . . . the ideal control for varying the a-c voltage applied to any electrical, electronic, radar or communications equipment. Voltages from Zero to 17% above line are obtained by a 320-degree rotation of the shaft, which is equipped with a direct-reading dial, calibrated accurately.

"VARIAC" offers many real advantages over any other type of a-c control: compared with the losses of resistive controls they save their initial cost within about one year. They are available in various sizes from 170 VA up to 25 Kilowatts. 3-gang assemblies are also available for 3-phase working. Prices vary from £7.10.0 upwards.

Write for our Catalogue—Technical Manual V.549, which gives all possible information.

Request also our 20-page Supplementary Catalogue giving complete information on our new and complete range of A.C. Automatic Voltage Stabilisers: These range from 200 VA to 25 kVA. Performance is excellent, from No-Load to Full Load, and stability is quite unaffected by frequency variations. Prices are exceptionally low.

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Claude Lyons Ltd. are exclusive distributors of GENERAL RADIO equipment in this country. If you require information about their extensive range of instruments please tick appropriate square(s).

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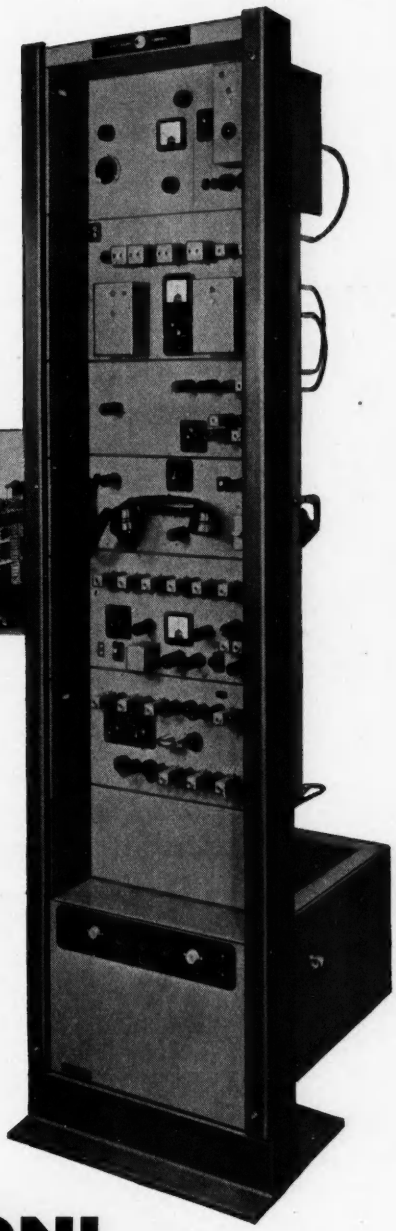
Marconi VHF Multi-Channel Equipment

TYPE HM 181



Multi-channel radio links are not only recognised economic alternatives to line and cable routes wherever the latter are costly because of intensive urban development or the wild nature of the terrain; they are frequently preferable in their own right. The type HM 181 equipment has been designed for comparatively simple schemes using two terminals working point-to-point or with a limited number of repeaters. It operates in the frequency range 150-200 Mc/s, employs frequency modulation and gives high performance with low distortion.

It provides the following facilities:—

8, 16 or 24 channels.
Repeaters with easy channel dropping facilities.
Unattended operation.
Engineers' order wire.
Ease of access for maintenance.

MARCONI

COMPLETE COMMUNICATION SYSTEMS

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LC 6

A NEW TECHNIQUE IN HIGH SPEED WAVEFORM MONITORING

BANDWIDTH :
10 kc/s to 300 mc/s

INPUT IMPEDANCE OF EACH PROBE :
Approx. 1 pf (input element of variable capacity divider)

MAXIMUM SENSITIVITY :
Full Scale Deflection for 1 Volt input

TIME SCALE :
Variable from .05 microsecs to 5 microsecs

RECURRENCE RATE OF MONITORED WAVEFORM :
100 c/s to 10 kc/s

CALIBRATION :
Provision is made for accurate measurement of time and voltage scales of a waveform

PREVENTION OF JITTER :
A circuit is incorporated for providing a stable display when a monitored waveform is jittering with respect to its driving pulse.

HIGH SPEED RECURRENT WAVEFORM MONITOR TYPE 500

The wide bandwidth and high sensitivity of the instrument as well as the very high input impedance result from the use of a sampling technique. During each recurrence a measurement is made of the instantaneous amplitude of one point in the waveform. This measurement is amplified and applied to the cathode ray tube as one co-ordinate of a graph of the waveform. During subsequent recurrences, instantaneous measurements are made of different points, resulting, after about 100 recurrences, in a complete graph.

Please write for further information.

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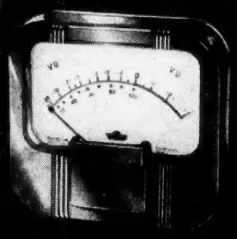
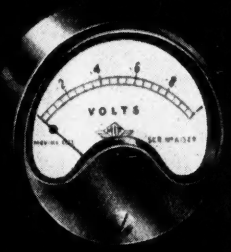
the answer to many problems

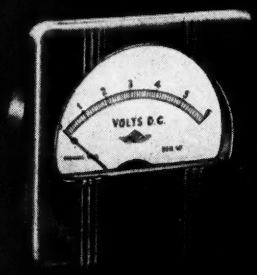
. . . . . will be found within the pages of the Pullin Electrical Measuring Instrument Catalogue. A copy by your side will enable you to plan the instrumentation of your electrical installations at the drawing board stage, and save much time and money later on. Write for a copy stating the particular range of instruments in which you are interested.



SERIES 35, 3½" DIAL V.U. METER for power level indication.

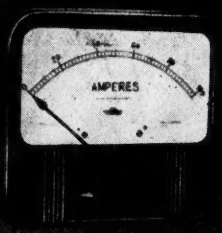


SERIES 20, 2" DIAL MINIATURE RANGE. Round projecting type also available in round or square flush pattern.



SERIES 25, 2½" DIAL MINIATURE RANGE. Square flush type also available in round projecting or round flush pattern.

ROUND PROJECTING TYPE SWITCHBOARD INSTRUMENT (4" AND 6" DIAL SIZES). In pressed steel case. Convertible to flush mounting by separate attachment.



RECTANGULAR FLUSH PATTERN INSTRUMENT. With circular pressed steel base and moulded front cover. Heavy duty cast iron front cover also available.

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Measuring Instruments Dynamometer Testing Sets Frequency Meters

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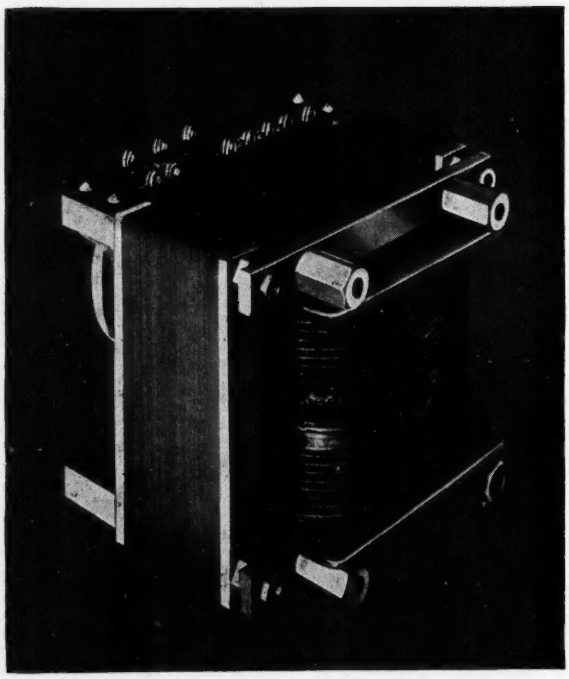
PHONE: ACORN 4651-3 AND 4995.

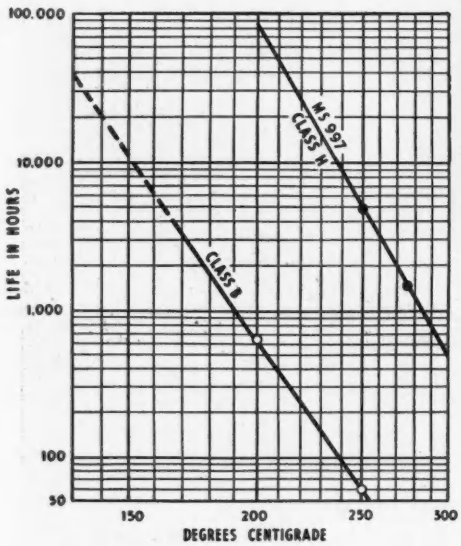
SILICONE INSULATION

in electronic equipment

Silicone-bonded insulation includes resin-bonded glasscloth laminates in rod, tube and sheet form that can be machined and fabricated; varnished glasscloth from 0.004in. thick; micanite and mica/glasscloth; varnished glasscloth and silicone rubber sleevings and silicone-enamelled winding wire. Coils are impregnated with silicone varnish MS997. Silicone insulation will withstand operating temperatures at least 50°C. higher than conventional insulation. Where extreme compactness of design is necessary, particularly if excessive temperature rises are likely, silicone insulation is recommended.



A recent, typical example of a component designed for silicone insulation is the power transformer made by Marconi's Wireless Telegraph Co. Ltd. for use in B.B.C. television cameras. These transformers are insulated with silicone-bonded materials and impregnated with silicone varnish for operation up to 150°C. By using silicone insulation the transformers give more power per pound weight than with any other form of insulation.



THIS GRAPH compares the thermal endurance of silicone varnishes. The "life" is based on the hours necessary to reduce the electric strength of varnished glasscloth to half its initial value. Measurements were made on strips of heat-cleaned 0.004 in. glasscloth. Each strip was dip-coated with the varnish, cured and then dipped and cured again to give a finished thickness of 0.007 ± 0.001 in.

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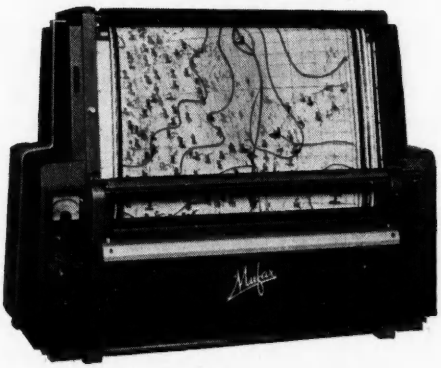
MAKERS OF HIGH GRADE PRECISION ELECTRICAL INSTRUMENTS

MUIRHEAD PICTURE TELEGRAPH EQUIPMENT

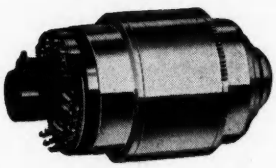


D-649 18" MUFAX CHART RECORDER

MUIRHEAD

A comprehensive range of phototelegraphic transmitters and receivers for line and radio working. Mufax chart recorders and picture receivers, employing a method of continuous non-photographic recording on inexpensive Mufax electro-sensitive paper.

MUIRHEAD MAGSLIPS

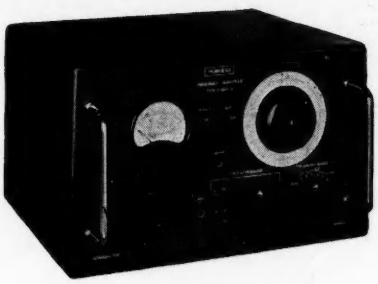


E-24-C MAGSLIP RESOLVER

MUIRHEAD

Magslip elements of various sizes for remote indication and control, for computation and summation, and for use in servo systems. Motors and amplifiers for servo purposes and other small-power applications.

MUIRHEAD INSTRUMENTS



D-669 FREQUENCY ANALYSER

MUIRHEAD

Resistance - capacitance — tuned audio - frequency oscillators, decade and continuously variable, for frequencies from 0.1c/s to 100kc/s. Valve-maintained tuning forks, phonic motors and observatory timing devices. Instruments for waveform analysis and vibration measurement.

OTHER MUIRHEAD PRODUCTS INCLUDE:—

Decade resistance boxes · Wire-wound resistors · Attenuators · Variable Air Capacitors
AC bridges · DC laboratory equipment · Key and stud switches · Instrument dials and drives
Audio-frequency transformers

134

Write under your business letterhead for our catalogue

RELAYS

SERIES
595 H

HERMETICALLY SEALED
SERIES 595 H

This is a hermetically sealed version of our series 595 Relay, which is already well known to the aircraft industry.

The armature design reduces the effects of shock, vibration and acceleration ; a spring type armature hinge eliminates backlash, friction and risk of displacement.

COIL: In all standard voltages up to 110 V. D.C. Working range between plus 10% and minus 20% of rating.

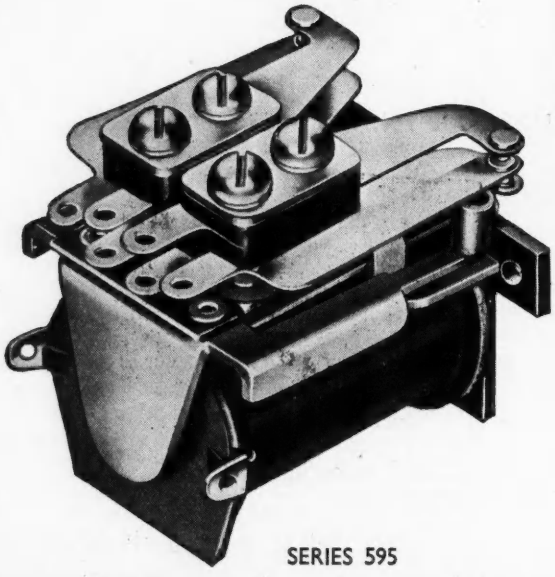
CONTACT COMBINATIONS: up to 2 pole changeover.

BASE: International octal.

WEIGHT: $3\frac{1}{4}$ ozs.

DIMENSIONS :

Diameter—$1\frac{11}{16}$" overall.
Height —$2\frac{5}{8}$" overall.



SERIES 595

MAGNETIC DEVICES LTD
NEWMARKET

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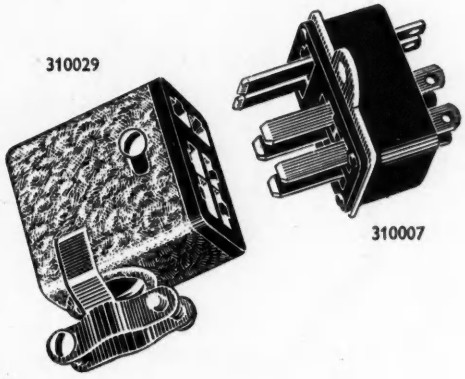
By Appointment to the Professional Engineer

PAINTON "MULTICON" SERIES
6-POLE PLUGS & SOCKETS

'MULTICON'—Regd. Trade Mark PATENT 700999



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D.C. or A.C. Peak

CURRENT CARRYING CAPACITY
5 amps. D.C. or A.C. (RMS) per contact

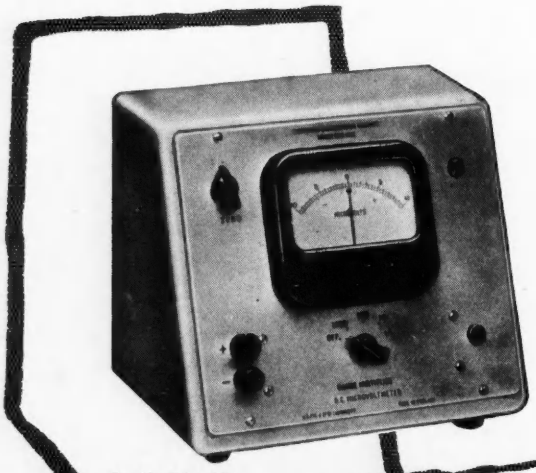
Although in general the new Painton "Multicon" Series of Plugs and Sockets will be interchangeable with the existing Painton range, the 6-pole Plugs and Sockets have two contacts polarised to eliminate the possibility of 'wrong-way-round' insertion. In the 6-pole size (as on all other "Multicon" sizes when available) there is a complete variety of Plugs and Sockets with alternative mounting arrangements, cable fixings and retaining devices. The "Hammer-finish" silver-grey covers will blend with all equipments.

A low and constant contact resistance is achieved with the heavily silver-plated split contacts.

Any possibility of free moisture remaining between the Plug and Socket face is prevented because spacers keep the mating faces slightly apart, even when the Plugs and Sockets are fully engaged. The patented method of securing both the male and female contacts in the mouldings ensures the satisfactory operation of the Painton "Multicon" range under severe tropical and climatic conditions.

PLUG			SOCKET		
Cable Entry Top	Cable Entry Side	With Mounting Flange	Cable Entry Top	Cable Entry Side	With Mounting Flange
310009	310018	310007	310008	310029	310006
FITTED WITH LOCKING CLIP			FITTED WITH LOCKING CLIP		
311291	311292	—	311294	311295	—

PAINTON
Northampton England



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PYE SENSITIVE D.C. MICROVOLTMETER AND AMPLIFIER

This new instrument has several important applications. It replaces the sensitive reflecting galvanometer as a detector in potentiometer and bridge circuits. The rapid response, easily-read deflections, and ability to be used on an ordinary bench offer great advantages for routine industrial measurements. It may also be used as a low-frequency d.c. amplifier of exceptional zero stability and low cost. A jack-socket at the back allows output to be taken to controllers, recorders, or relays. Thermocouples, resistance bridge net-works, barrier-layer photocells, or any device giving a small voltage signal can be connected to the input. The fact that voltages as low as 1μV can be handled opens new possibilities in this field.

SCALE:
10μV-0-10μV.

RANGES:
X1, X10, X100, X1000.

INPUT RESISTANCE:
40 ohms.

RESPONSE TIME:
On X 1 range 0.5 seconds;
on other ranges 0.15 seconds.

ZERO DRIFT:
Not more than ± 1μV/hour.

OUTPUT CURRENT:
1 mA into 4000 ohms.
(When used as d.c. Amplifier)

POWER SUPPLY
110, 200-250V, 40-60c/s.

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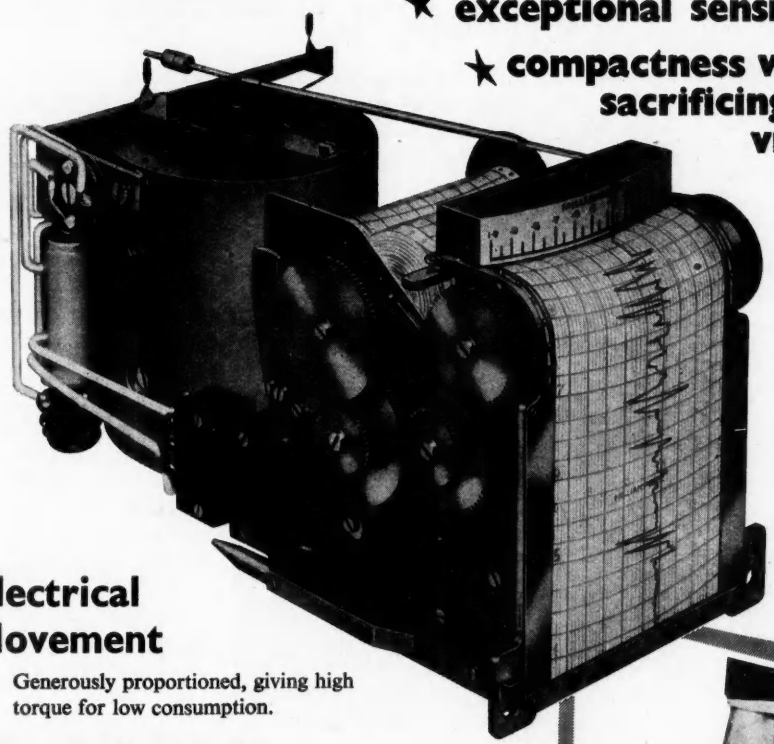
★ compactness without sacrificing chart visibility



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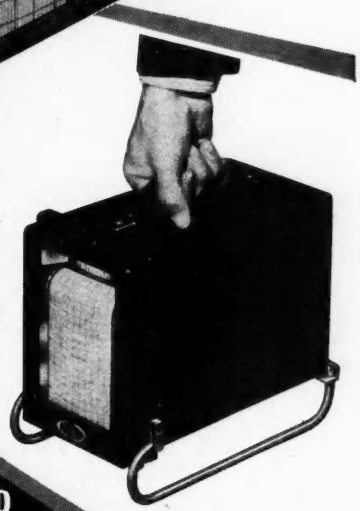

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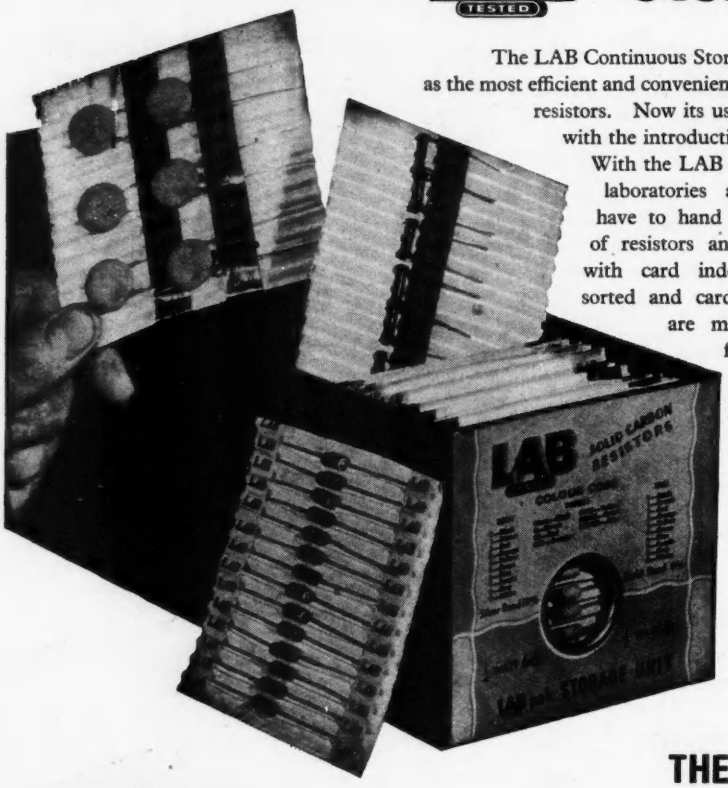

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RESISTORS					
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R	¼ watt	1 watt	500		⅝" × ¼"
Tolerance available ±20%, 10%, 5%					
HIGH STABILITY RESISTORS					
HS3	¼ watt	¼ watt	750	1 ohm to 500 megohms	1.1" × 0.1"
Tolerance available ±5%, 2%, 1%					
WIREWOUND RESISTORS 5 ohms to 100K ohms — 5 - 10 watts					
'CERAMICAPS' Tubulars 3 - 470 pf Tolerances ±2%, 10% 500 - 5000 pf Hi-K					

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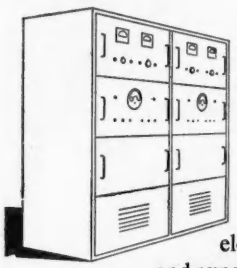

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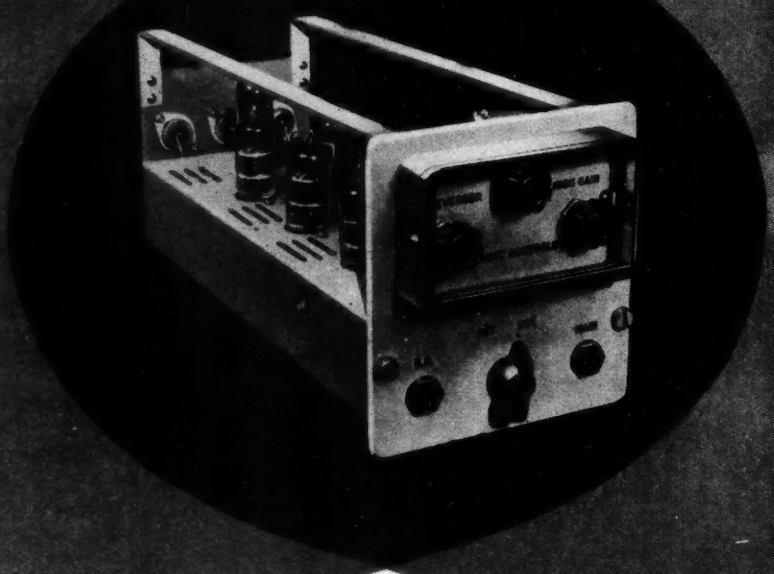

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Main amplifier, drift corrected (high gain)	2×10^7 at zero frequency
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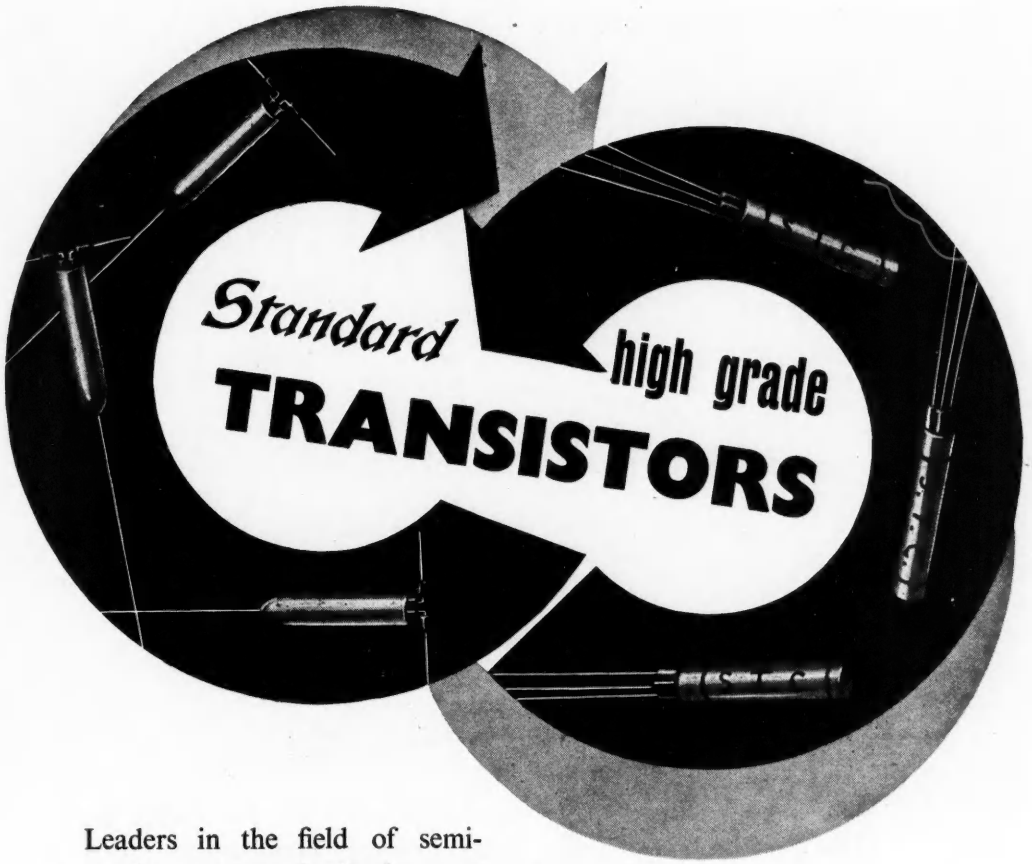

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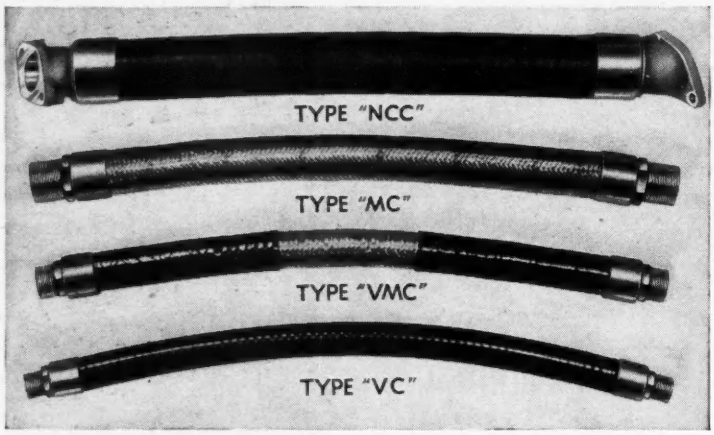

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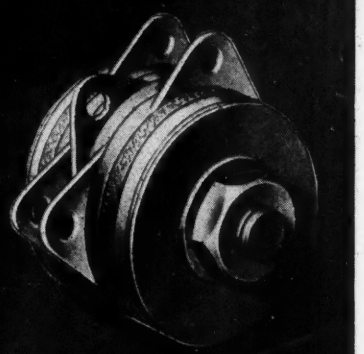

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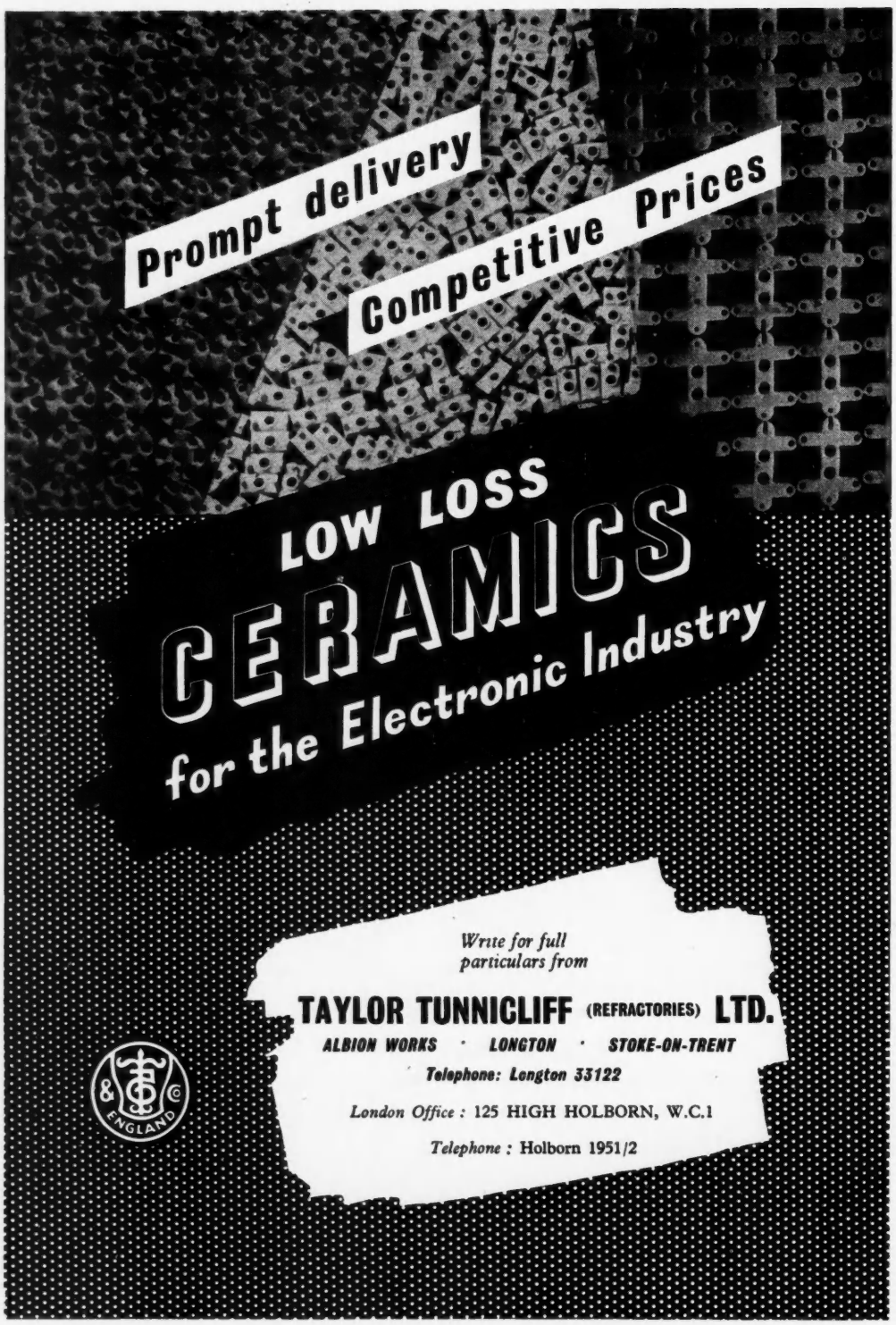
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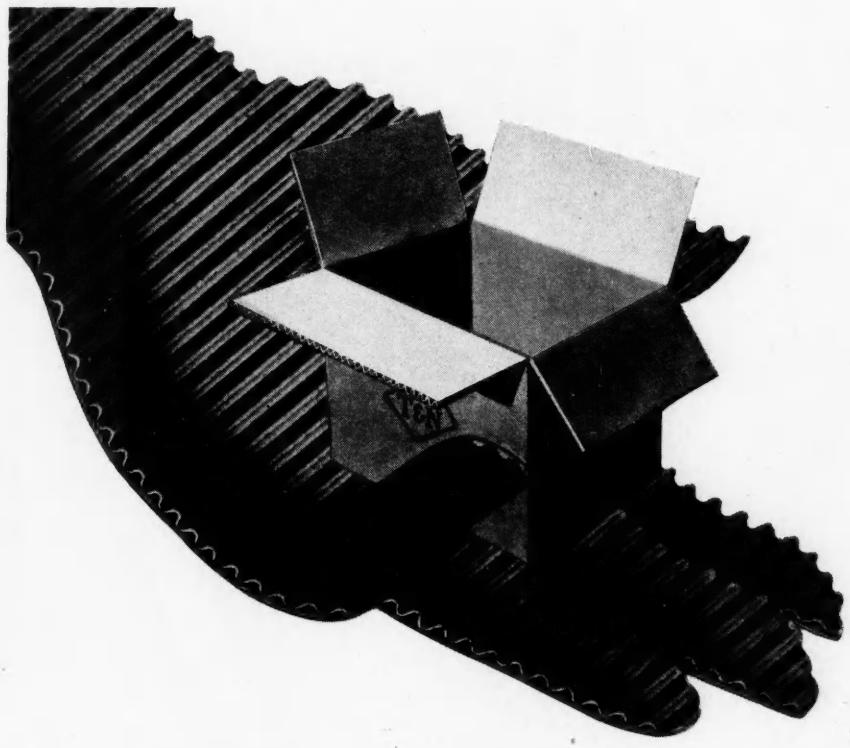

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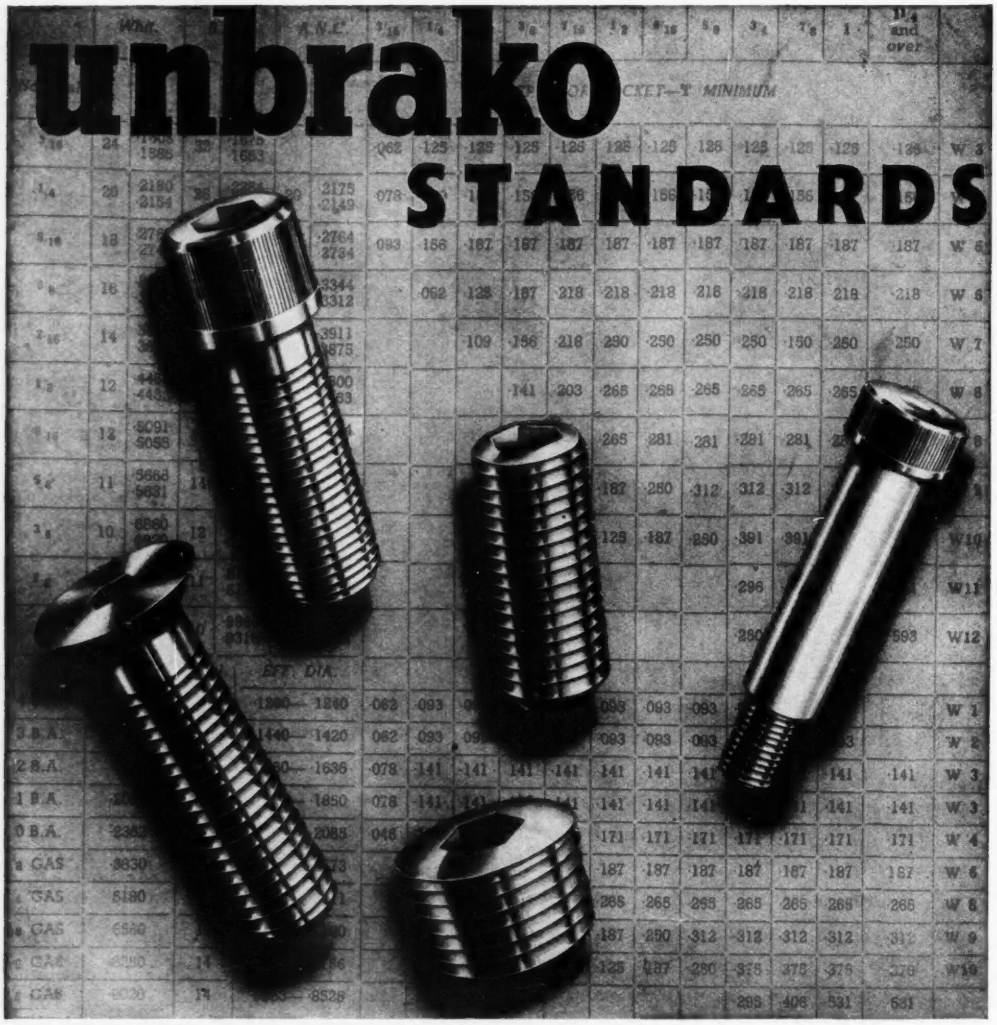

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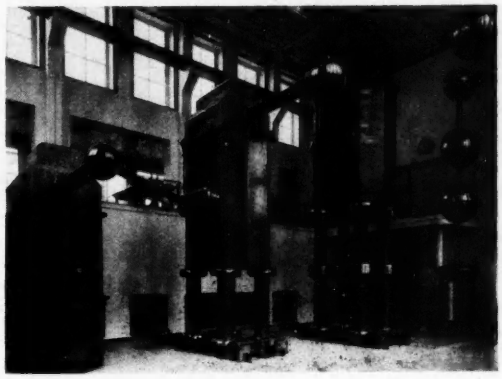

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XFR3	H.F. Triode ...	**5676**	1·25	120	135		−5	4·0		1·65 mA/V	
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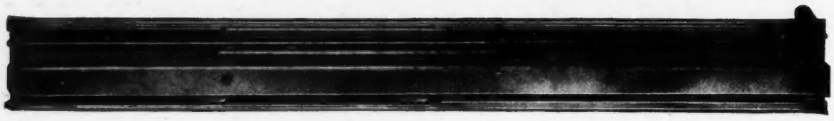

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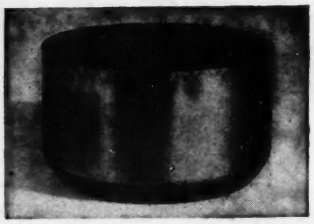

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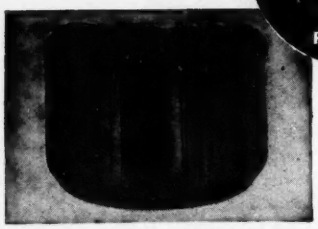

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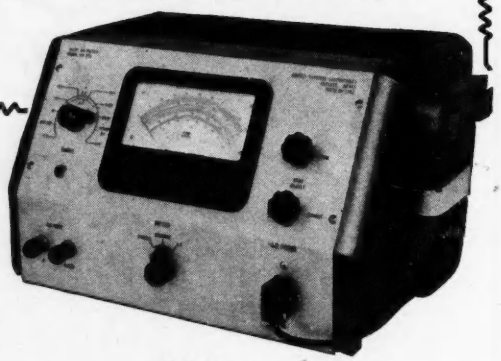
Model VM853



- *WIDE RANGE OF VOLTAGE MEASUREMENTS*
- *HIGHEST POSSIBLE INPUT RESISTANCE ON ALL RANGES*
- *MEASURES FROM D.C. TO U.H.F*

On the lower D.C. ranges, this instrument approaches conditions of an electrostatic voltmeter and on A.C. ranges a measuring diode contained in an external probe, is provided. To minimize the effect of the metal body of the probe, the insulated terminal head can be replaced by a spike. All-range indicator consists of a 5-inch meter fitted with knife-edge pointer and mirror scale. Send for leaflet giving full specification.

	D.C. Ranges	*A.C. Ranges*
Volt -	0-300 *mV*	0-1 *V*
Ranges -	0-1 *V* - 0-300 *V*	0-3 *V* - 0-100 *V*
Accuracy	±2% *of f.s.d.*	±2% *of f.s.d.*
Input -	*For the first five ranges, 25 megohms*	*20 megohms up to medium* R.F., *on all ranges*

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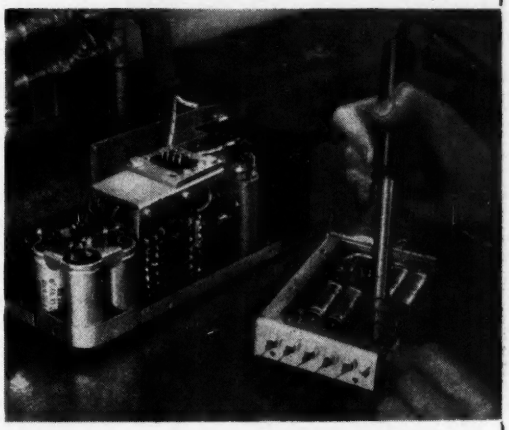

Soldering operation on the power-pack vibrator unit of a sub-miniature communications receiver.

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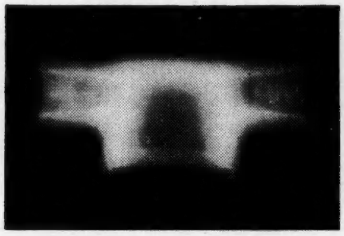

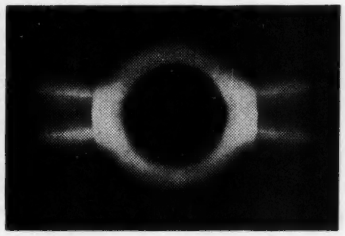

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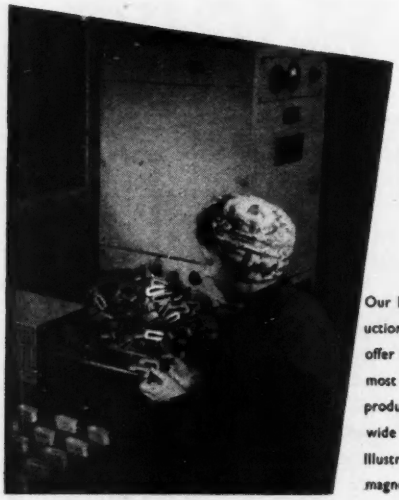

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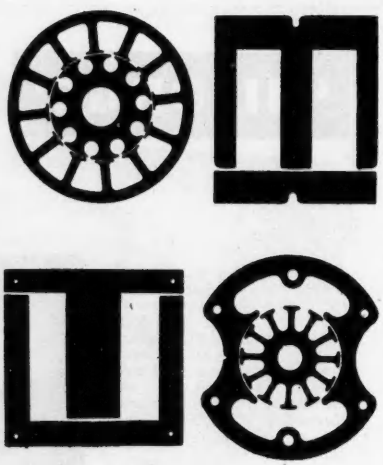

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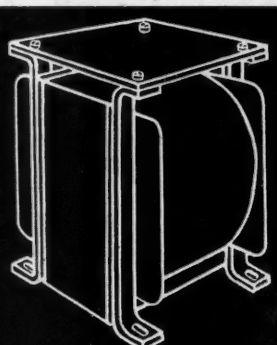

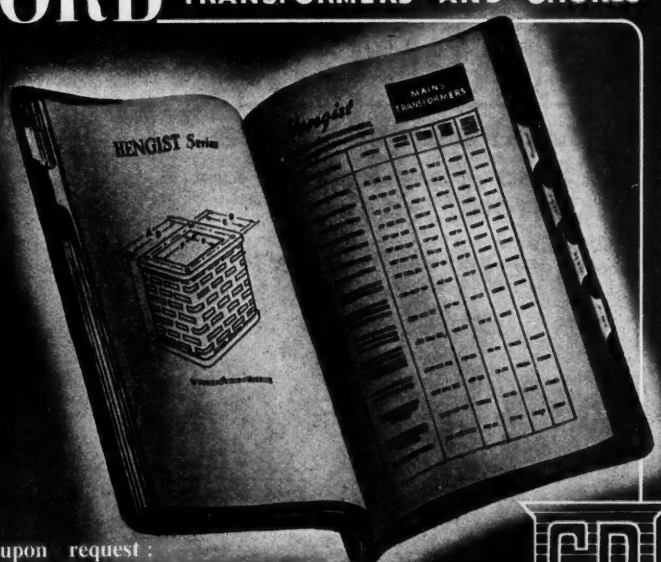

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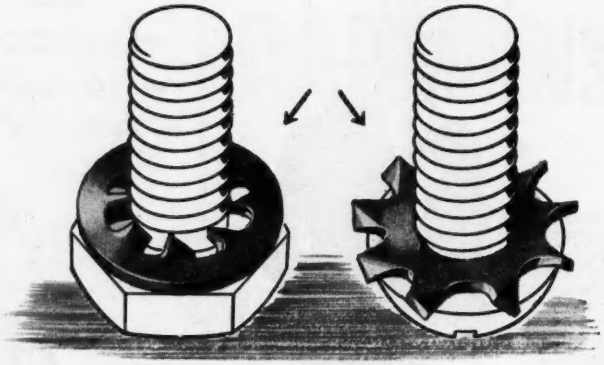

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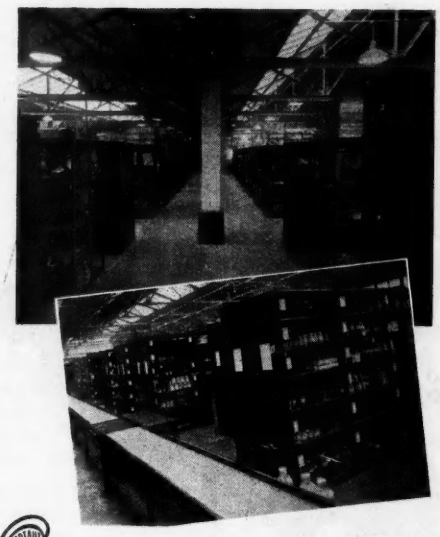

Illustrated above are the types of installations as used by the Warwickshire County Council and Messrs. Baird and Tatlock (London) Ltd. The former shows both open and closed type shelving and the latter the closed type for chemical and laboratory supplies.

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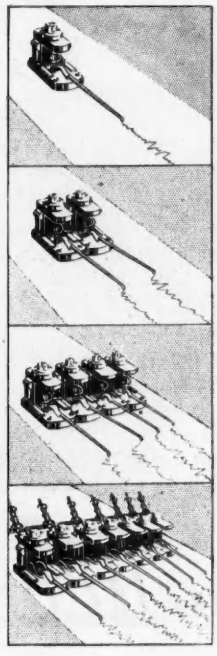

★ **Full deflection in 2½ milli-seconds**

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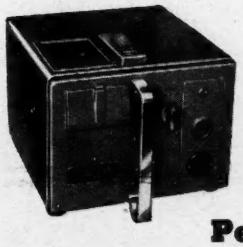

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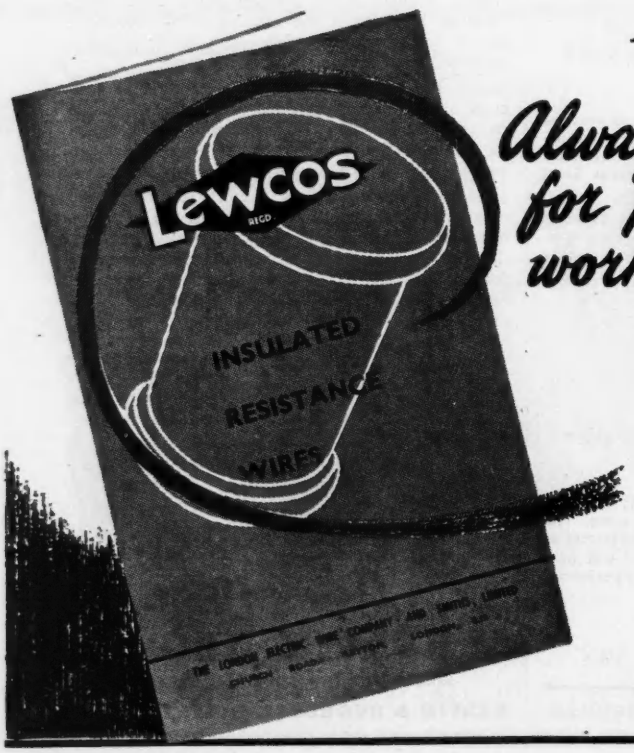

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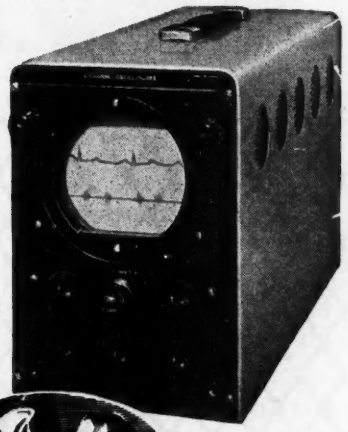

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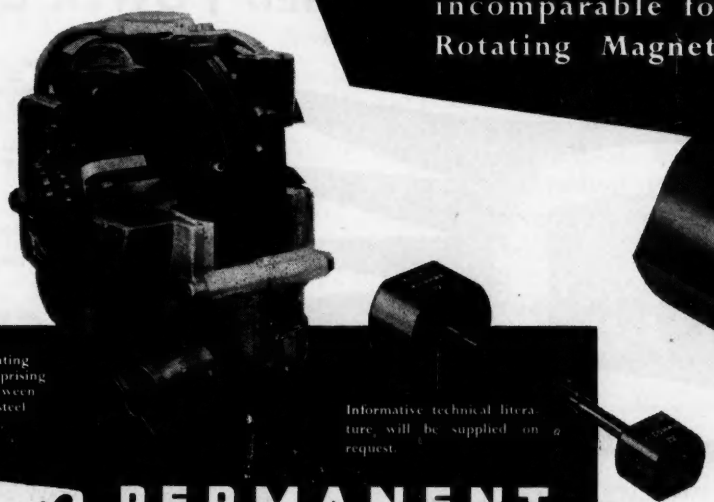

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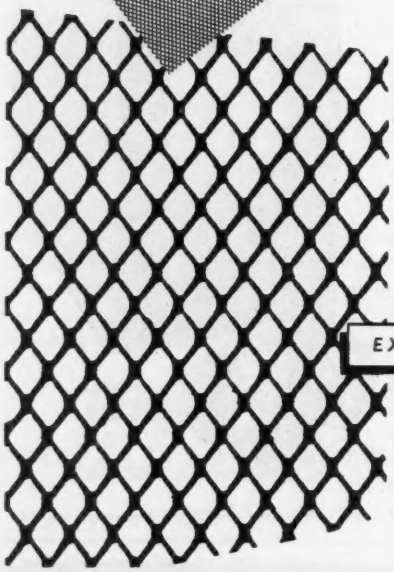

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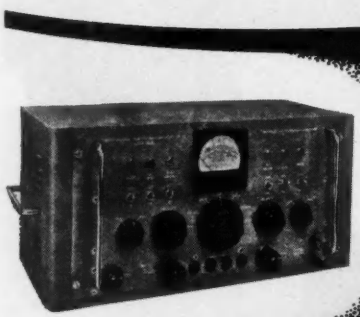

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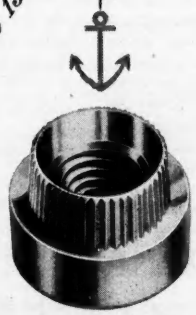

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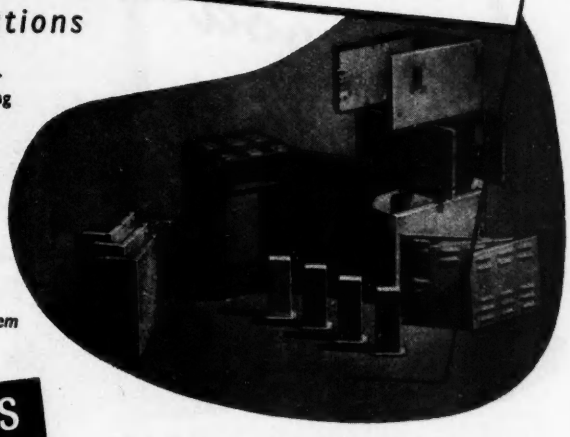

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Metalised Paper	65%
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Stantelum Electrolytic Capacitors do not deteriorate with shelf life.

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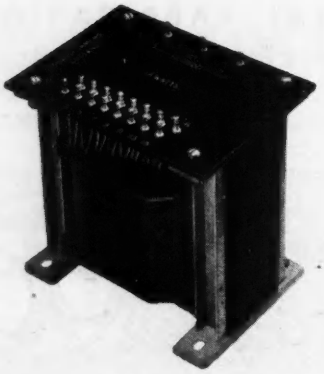

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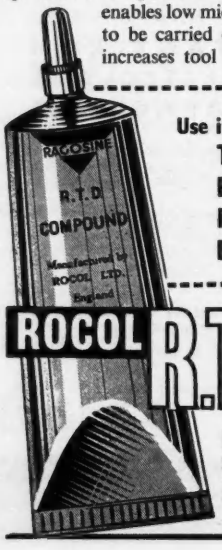

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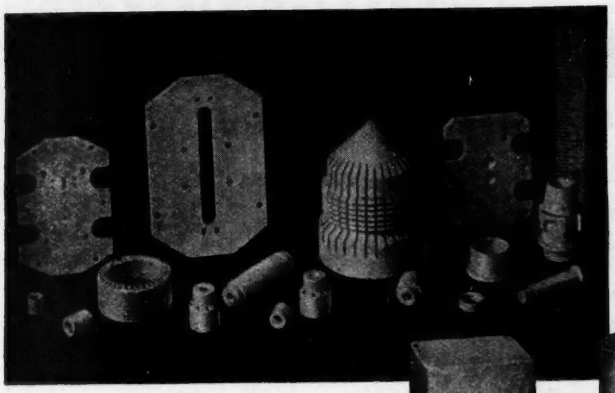

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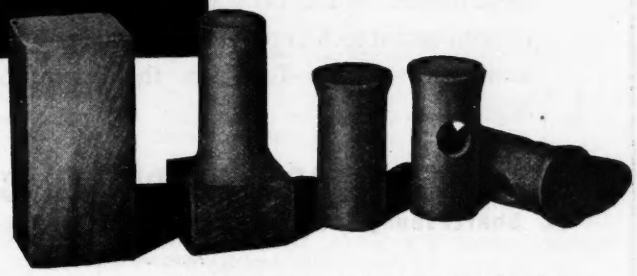

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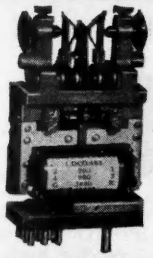

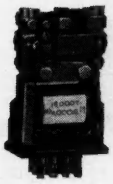

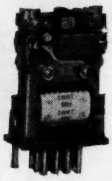

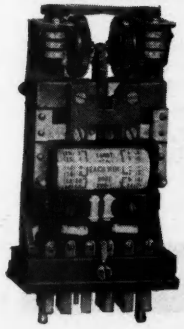

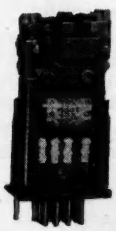

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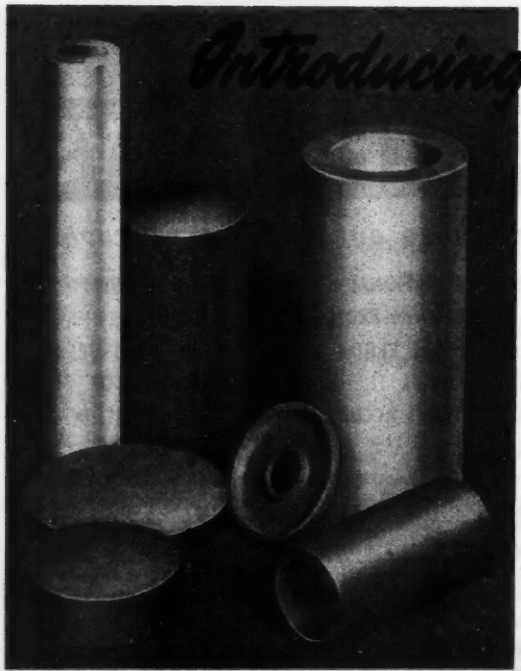

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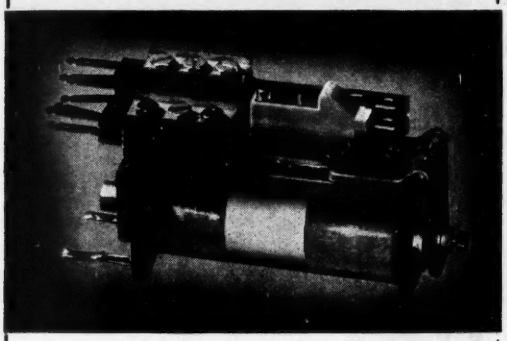

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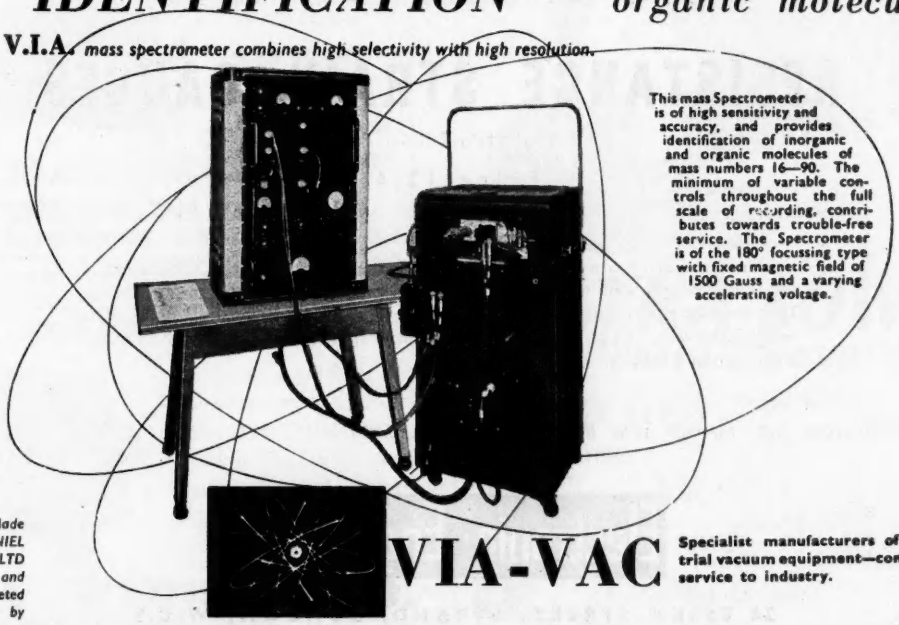

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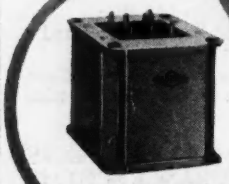
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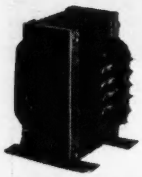
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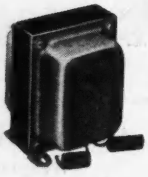
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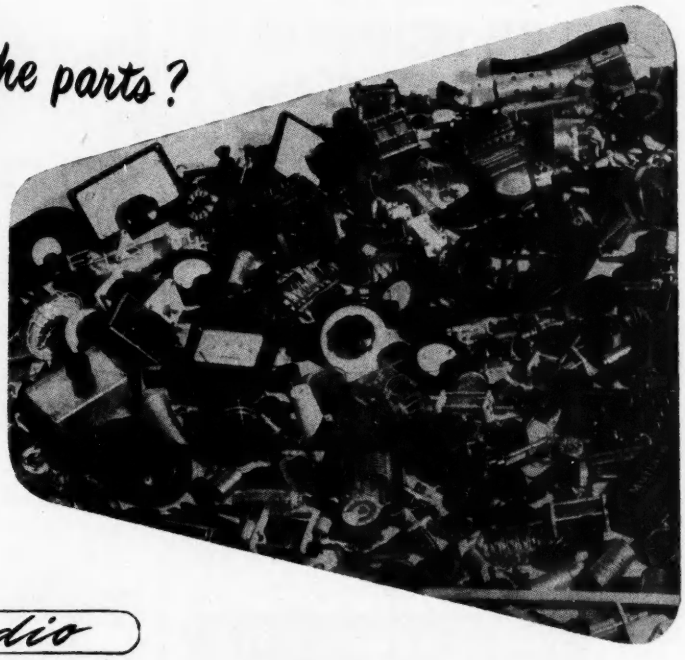

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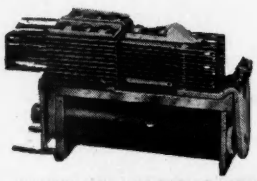

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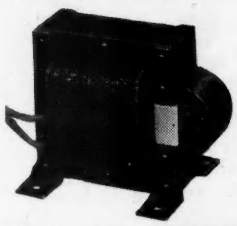

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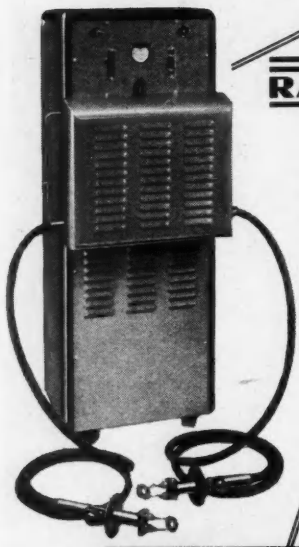

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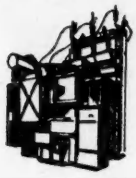

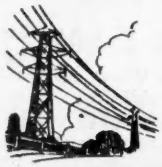

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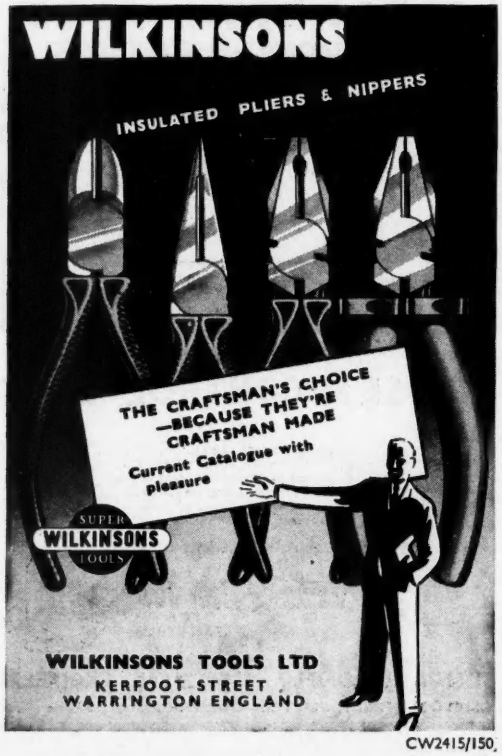

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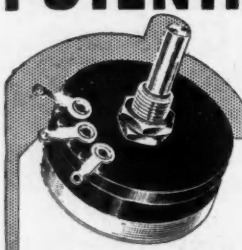

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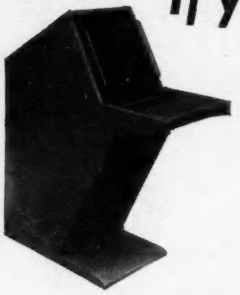

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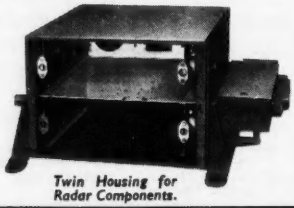

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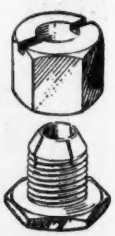

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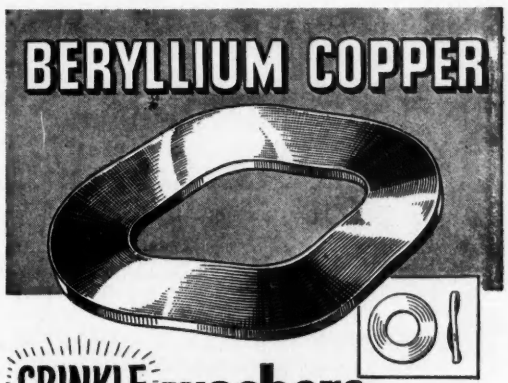

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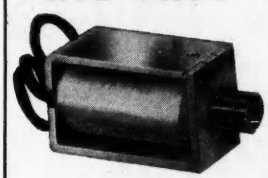

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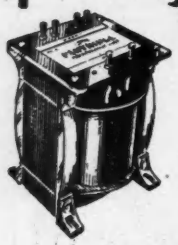

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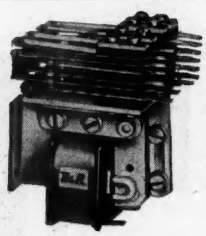

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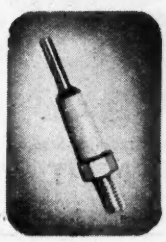

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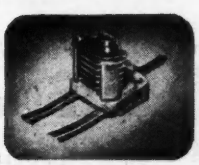

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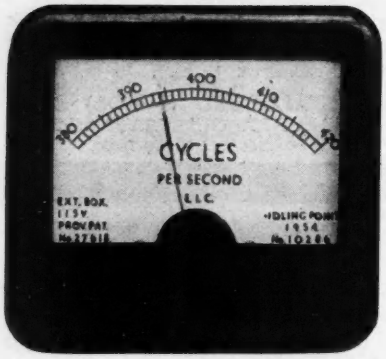

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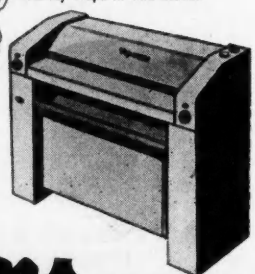

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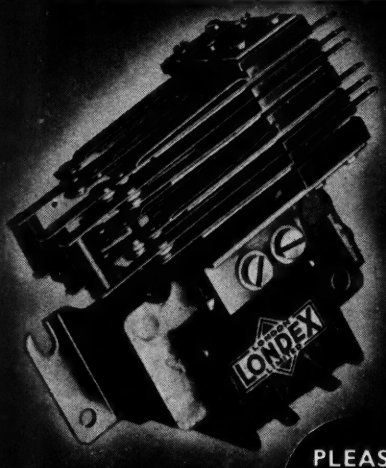

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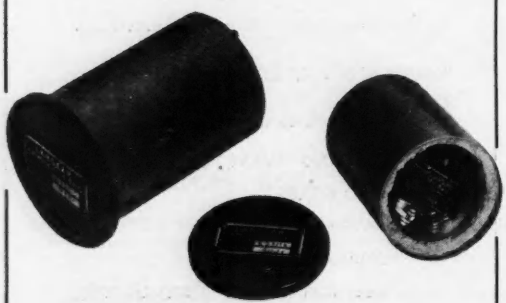

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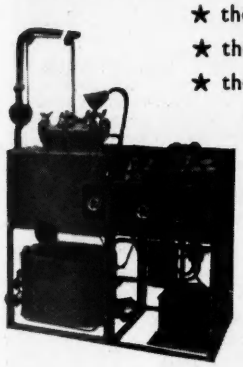

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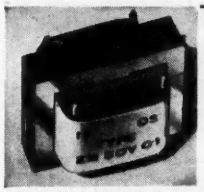

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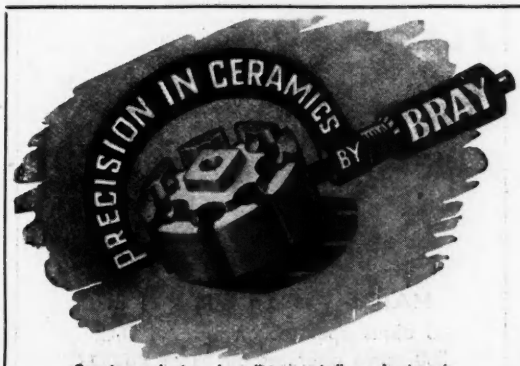

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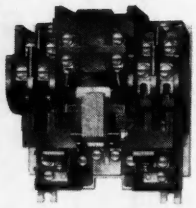

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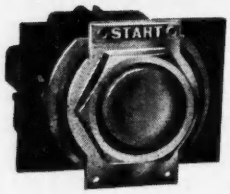

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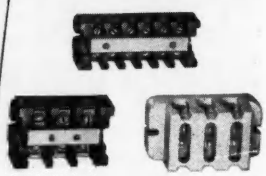

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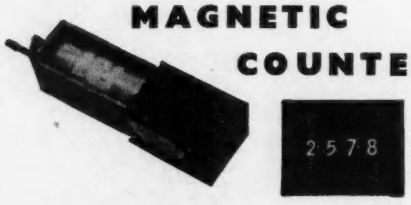

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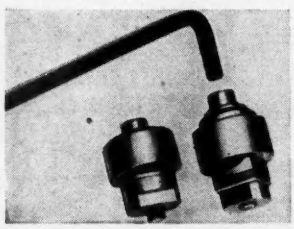

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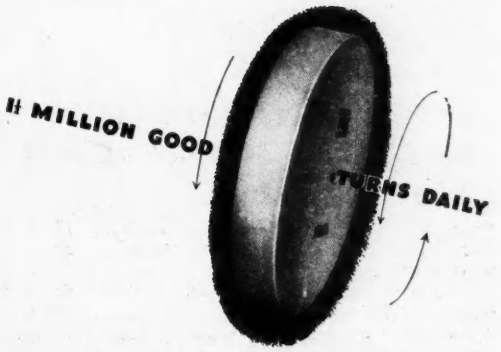

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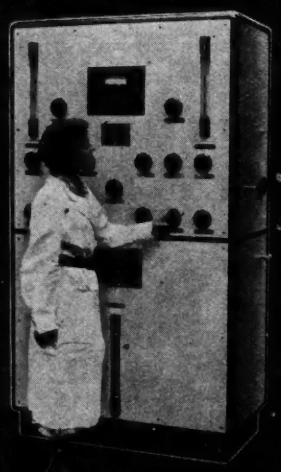

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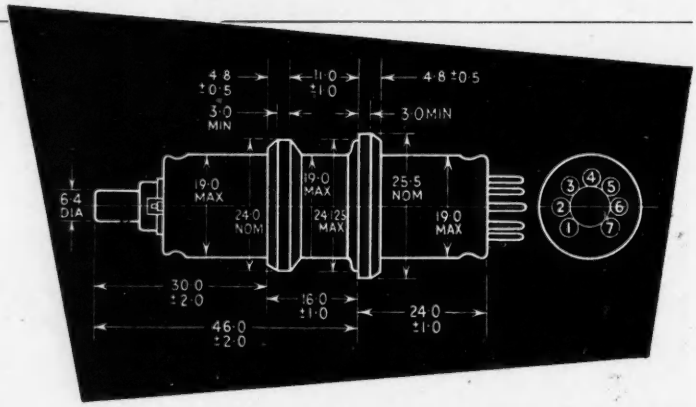

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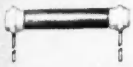

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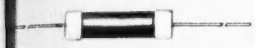

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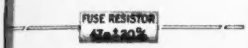

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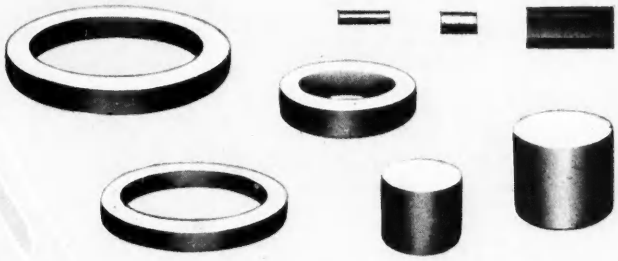

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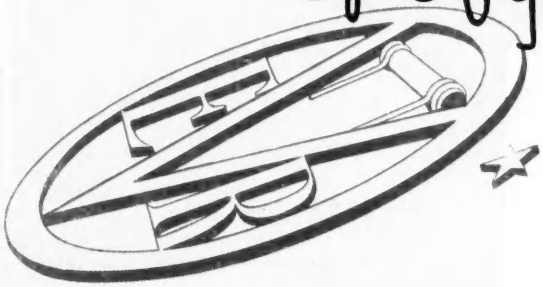

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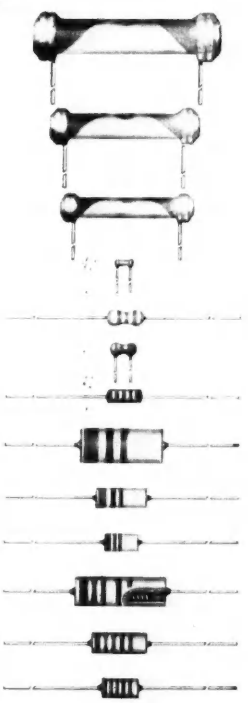

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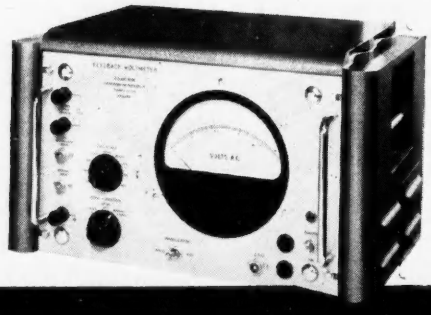
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